

# Package ‘simStateSpace’

January 14, 2024

**Title** Simulate Data from State Space Models

**Version** 1.1.0

**Description** Provides a streamlined and user-friendly framework for simulating data in state space models, particularly when the number of subjects/units (n) exceeds one, a scenario commonly encountered in social and behavioral sciences. For an introduction to state space models in social and behavioral sciences, refer to Chow, Ho, Hamaker, and Dolan (2010) <[doi:10.1080/10705511003661553](https://doi.org/10.1080/10705511003661553)>.

**URL** <https://github.com/jeksterslab/simStateSpace>,  
<https://jeksterslab.github.io/simStateSpace/>

**BugReports** <https://github.com/jeksterslab/simStateSpace/issues>

**License** GPL (>= 3)

**Encoding** UTF-8

**Roxygen** list(markdown = TRUE)

**Depends** R (>= 3.0.0)

**LinkingTo** Rcpp, RcppArmadillo

**Imports** Rcpp

**Suggests** knitr, rmarkdown, testthat, Matrix

**RoxygenNote** 7.3.0

**NeedsCompilation** yes

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as.data.frame.ssm	<i>Coerce an Object of Class ssm to a Data Frame</i>
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**Description**

Coerce an Object of Class ssm to a Data Frame

**Usage**

```
## S3 method for class 'ssm'
as.data.frame(
  x,
  row.names = NULL,
  optional = FALSE,
  eta = FALSE,
  long = TRUE,
  ...
)
```

**Arguments**

x	Object of class ssm.
row.names	NULL or character vector giving the row names for the data frame. Missing values are not allowed.
optional	Logical. If TRUE, setting row names and converting column names is optional.
eta	Logical. If eta = TRUE, include eta. If eta = FALSE, exclude eta.
long	Logical. If long = TRUE, use long format. If long = FALSE, use wide format.
...	Additional arguments.

**Author(s)**

Ivan Jacob Agaloos Pesigan

**Examples**

```

# prepare parameters
set.seed(42)
k <- p <- 3
iden <- diag(k)
null_vec <- rep(x = 0, times = k)
n <- 5
mu0 <- null_vec
sigma0 <- iden
alpha <- null_vec
beta <- diag(x = 0.50, nrow = k)
psi <- iden
nu <- null_vec
lambda <- iden
theta <- diag(x = 0.50, nrow = k)
time <- 50
burn_in <- 0
gamma_y <- gamma_eta <- 0.10 * diag(k)
x <- lapply(
  X = seq_len(n),
  FUN = function(i) {
    return(
      matrix(
        data = rnorm(n = k * (time + burn_in)),
        ncol = k
      )
    )
  }
)

# Type 0
ssm <- SimSSMFixed(
  n = n,
  mu0 = mu0,
  sigma0 = sigma0,
  alpha = alpha,
  beta = beta,
  psi = psi,
  nu = nu,
  lambda = lambda,
  theta = theta,
  type = 0,
  time = time,
  burn_in = burn_in
)

as.data.frame(ssm)

```

**Description**

Coerce an Object of Class ssm to a Matrix

**Usage**

```
## S3 method for class 'ssm'
as.matrix(x, eta = FALSE, long = TRUE, ...)
```

**Arguments**

x	Object of class ssm.
eta	Logical. If eta = TRUE, include eta. If eta = FALSE, exclude eta.
long	Logical. If long = TRUE, use long format. If long = FALSE, use wide format.
...	Additional arguments.

**Author(s)**

Ivan Jacob Agaloos Pesigan

**Examples**

```
# prepare parameters
set.seed(42)
k <- p <- 3
iden <- diag(k)
null_vec <- rep(x = 0, times = k)
n <- 5
mu0 <- null_vec
sigma0 <- iden
alpha <- null_vec
beta <- diag(x = 0.50, nrow = k)
psi <- iden
nu <- null_vec
lambda <- iden
theta <- diag(x = 0.50, nrow = k)
time <- 50
burn_in <- 0
gamma_y <- gamma_eta <- 0.10 * diag(k)
x <- lapply(
  X = seq_len(n),
  FUN = function(i) {
    return(
      matrix(
        data = rnorm(n = k * (time + burn_in)),
        ncol = k
      )
    )
  }
)
```

```
# Type 0
ssm <- SimSSMFxed(
  n = n,
  mu0 = mu0,
  sigma0 = sigma0,
  alpha = alpha,
  beta = beta,
  psi = psi,
  nu = nu,
  lambda = lambda,
  theta = theta,
  type = 0,
  time = time,
  burn_in = burn_in
)

as.matrix(ssm)
```

OU2SSM

*Convert Parameters from the Ornstein–Uhlenbeck Model to State Space Model Parameterization*

### Description

This function converts parameters from the Ornstein–Uhlenbeck model to state space model parameterization. See details for more information.

### Usage

```
OU2SSM(mu, phi, sigma, delta_t)
```

### Arguments

mu	Numeric vector. The long-term mean or equilibrium level ( $\mu$ ).
phi	Numeric matrix. The rate of mean reversion, determining how quickly the variable returns to its mean ( $\Phi$ ).
sigma	Numeric matrix. The matrix of volatility or randomness in the process ( $\Sigma$ ).
delta_t	Numeric. Time interval ( $\delta_t$ ).

### Details

The state space parameters as a function of the Ornstein–Uhlenbeck model parameters are given by

$$\beta = \exp(-\Phi \Delta_t)$$

$$\alpha = -\Phi^{-1}(\beta - \mathbf{I}_p)$$

$$\text{vec}(\Psi) = \{ [(-\Phi \otimes \mathbf{I}_p) + (\mathbf{I}_p \otimes -\Phi)] [\exp([(-\Phi \otimes \mathbf{I}_p) + (\mathbf{I}_p \otimes -\Phi)] \Delta_t) - \mathbf{I}_{p \times p}] \text{vec}(\Sigma) \}$$

**Value**

Returns a list of state space parameters:

- alpha: Numeric vector. Vector of intercepts for the dynamic model ( $\alpha$ ).
- beta: Numeric matrix. Transition matrix relating the values of the latent variables at time  $t - 1$  to those at time  $t$  ( $\beta$ ).
- psi: Numeric matrix. The process noise covariance matrix ( $\Psi$ ).

**Author(s)**

Ivan Jacob Agaloos Pesigan

**See Also**

Other Simulation of State Space Models Data Functions: [SimSSMFixed\(\)](#), [SimSSMIVary\(\)](#), [SimSSMLinGrowthIVary\(\)](#), [SimSSMLinGrowth\(\)](#), [SimSSMOUFixed\(\)](#), [SimSSMOUIVary\(\)](#), [SimSSMOU\(\)](#), [SimSSMVARFixed\(\)](#), [SimSSMVARIVary\(\)](#), [SimSSMVAR\(\)](#), [SimSSM\(\)](#)

**Examples**

```
p <- k <- 2
mu <- c(5.76, 5.18)
phi <- matrix(
  data = c(0.10, -0.05, -0.05, 0.10),
  nrow = p
)
sigma <- matrix(
  data = c(2.79, 0.06, 0.06, 3.27),
  nrow = p
)
delta_t <- 0.10

OU2SSM(
  mu = mu,
  phi = phi,
  sigma = sigma,
  delta_t = delta_t
)
```

---

plot.ssm

---

*Plot Method for an Object of Class ssm*


---

**Description**

Plot Method for an Object of Class ssm

**Usage**

```
## S3 method for class 'ssm'
plot(x, id = NULL, time = NULL, eta = FALSE, type = "b", ...)
```

**Arguments**

x	Object of class ssm.
id	Numeric vector. Optional id numbers to plot. If id = NULL, plot all available data.
time	Numeric vector. Optional time points to plot. If time = NULL, plot all available data.
eta	Logical. If eta = TRUE, plot the latent variables. If eta = FALSE, plot the observed variables.
type	Character indicating the type of plotting; actually any of the types as in <a href="#">plot.default()</a> .
...	Additional arguments.

**Author(s)**

Ivan Jacob Agaloos Pesigan

**Examples**

```
# prepare parameters
set.seed(42)
k <- p <- 3
iden <- diag(k)
null_vec <- rep(x = 0, times = k)
n <- 5
mu0 <- null_vec
sigma0 <- iden
alpha <- null_vec
beta <- diag(x = 0.50, nrow = k)
psi <- iden
nu <- null_vec
lambda <- iden
theta <- diag(x = 0.50, nrow = k)
time <- 50
burn_in <- 0
gamma_y <- gamma_eta <- 0.10 * diag(k)
x <- lapply(
  X = seq_len(n),
  FUN = function(i) {
    return(
      matrix(
        data = rnorm(n = k * (time + burn_in)),
        ncol = k
      )
    )
  }
)
```

```

)

# Type 0
ssm <- SimSSMFixed(
  n = n,
  mu0 = mu0,
  sigma0 = sigma0,
  alpha = alpha,
  beta = beta,
  psi = psi,
  nu = nu,
  lambda = lambda,
  theta = theta,
  type = 0,
  time = time,
  burn_in = burn_in
)

plot(ssm)

```

---

print.ssm

---

*Print Method for an Object of Class ssm*


---

## Description

Print Method for an Object of Class ssm

## Usage

```
## S3 method for class 'ssm'
print(x, eta = FALSE, ...)
```

## Arguments

x	Object of Class ssm.
eta	Logical. If eta = TRUE, include eta. If eta = FALSE, exclude eta.
...	additional arguments.

## Value

Prints simulated data in long format.

## Author(s)

Ivan Jacob Agaloos Pesigan



**Examples**

```

# prepare parameters
set.seed(42)
k <- p <- 3
iden <- diag(k)
null_vec <- rep(x = 0, times = k)
n <- 5
mu0 <- null_vec
sigma0 <- iden
alpha <- null_vec
beta <- diag(x = 0.50, nrow = k)
psi <- iden
nu <- null_vec
lambda <- iden
theta <- diag(x = 0.50, nrow = k)
time <- 50
burn_in <- 0
gamma_y <- gamma_eta <- 0.10 * diag(k)
x <- lapply(
  X = seq_len(n),
  FUN = function(i) {
    return(
      matrix(
        data = rnorm(n = k * (time + burn_in)),
        ncol = k
      )
    )
  }
)

# Type 0
ssm <- SimSSMFixed(
  n = n,
  mu0 = mu0,
  sigma0 = sigma0,
  alpha = alpha,
  beta = beta,
  psi = psi,
  nu = nu,
  lambda = lambda,
  theta = theta,
  type = 0,
  time = time,
  burn_in = burn_in
)

print(ssm)

```

## Description

This function simulates data from a state space model. See details for more information.

## Usage

```
SimSSM(
  mu0,
  sigma0,
  alpha,
  beta,
  psi,
  nu,
  lambda,
  theta,
  gamma_y = NULL,
  gamma_eta = NULL,
  x = NULL,
  type = 0,
  time,
  burn_in = 0
)
```

## Arguments

mu0	Numeric vector. Mean of initial latent variable values ( $\mu_{\eta 0}$ ).
sigma0	Numeric matrix. The covariance matrix of initial latent variable values ( $\Sigma_{\eta 0}$ ).
alpha	Numeric vector. Vector of intercepts for the dynamic model ( $\alpha$ ).
beta	Numeric matrix. Transition matrix relating the values of the latent variables at time $t - 1$ to those at time $t$ ( $\beta$ ).
psi	Numeric matrix. The process noise covariance matrix ( $\Psi$ ).
nu	Numeric vector. Vector of intercepts for the measurement model ( $\nu$ ).
lambda	Numeric matrix. Factor loading matrix linking the latent variables to the observed variables ( $\Lambda$ ).
theta	Numeric matrix. The measurement error covariance matrix ( $\Theta$ ).
gamma_y	Numeric matrix. Matrix relating the values of the covariate matrix at time $t$ to the observed variables at time $t$ ( $\Gamma_y$ ).
gamma_eta	Numeric matrix. Matrix relating the values of the covariate matrix at time $t$ to the latent variables at time $t$ ( $\Gamma_{\eta}$ ).
x	Numeric matrix. The matrix of observed covariates in $\text{type} = 1$ or $\text{type} = 2$ . The number of rows should be equal to $\text{time} + \text{burn\_in}$ .
type	Integer. State space model type.
time	Positive integer. Number of time points to simulate.
burn_in	Positive integer. Number of burn-in points to exclude before returning the results.

## Details

### Type 0:

The measurement model is given by

$$\mathbf{y}_t = \boldsymbol{\nu} + \mathbf{\Lambda}\boldsymbol{\eta}_t + \boldsymbol{\varepsilon}_t \quad \text{with} \quad \boldsymbol{\varepsilon}_t \sim \mathcal{N}(\mathbf{0}, \boldsymbol{\Theta})$$

where  $\mathbf{y}_t$ ,  $\boldsymbol{\eta}_t$ , and  $\boldsymbol{\varepsilon}_t$  are random variables and  $\boldsymbol{\nu}$ ,  $\mathbf{\Lambda}$ , and  $\boldsymbol{\Theta}$  are model parameters.  $\mathbf{y}_t$  is a vector of observed random variables,  $\boldsymbol{\eta}_t$  is a vector of latent random variables, and  $\boldsymbol{\varepsilon}_t$  is a vector of random measurement errors, at time  $t$ .  $\boldsymbol{\nu}$  is a vector of intercepts,  $\mathbf{\Lambda}$  is a matrix of factor loadings, and  $\boldsymbol{\Theta}$  is the covariance matrix of  $\boldsymbol{\varepsilon}$ .

The dynamic structure is given by

$$\boldsymbol{\eta}_t = \boldsymbol{\alpha} + \boldsymbol{\beta}\boldsymbol{\eta}_{t-1} + \boldsymbol{\zeta}_t \quad \text{with} \quad \boldsymbol{\zeta}_t \sim \mathcal{N}(\mathbf{0}, \boldsymbol{\Psi})$$

where  $\boldsymbol{\eta}_t$ ,  $\boldsymbol{\eta}_{t-1}$ , and  $\boldsymbol{\zeta}_t$  are random variables, and  $\boldsymbol{\alpha}$ ,  $\boldsymbol{\beta}$ , and  $\boldsymbol{\Psi}$  are model parameters.  $\boldsymbol{\eta}_t$  is a vector of latent variables at time  $t$ ,  $\boldsymbol{\eta}_{t-1}$  is a vector of latent variables at time  $t - 1$ , and  $\boldsymbol{\zeta}_t$  is a vector of dynamic noise at time  $t$ .  $\boldsymbol{\alpha}$  is a vector of intercepts,  $\boldsymbol{\beta}$  is a matrix of autoregression and cross regression coefficients, and  $\boldsymbol{\Psi}$  is the covariance matrix of  $\boldsymbol{\zeta}_t$ .

### Type 1:

The measurement model is given by

$$\mathbf{y}_t = \boldsymbol{\nu} + \mathbf{\Lambda}\boldsymbol{\eta}_t + \boldsymbol{\varepsilon}_t \quad \text{with} \quad \boldsymbol{\varepsilon}_t \sim \mathcal{N}(\mathbf{0}, \boldsymbol{\Theta}).$$

The dynamic structure is given by

$$\boldsymbol{\eta}_t = \boldsymbol{\alpha} + \boldsymbol{\beta}\boldsymbol{\eta}_{t-1} + \boldsymbol{\Gamma}_\eta \mathbf{x}_t + \boldsymbol{\zeta}_t \quad \text{with} \quad \boldsymbol{\zeta}_t \sim \mathcal{N}(\mathbf{0}, \boldsymbol{\Psi})$$

where  $\mathbf{x}_t$  is a vector of covariates at time  $t$ , and  $\boldsymbol{\Gamma}_\eta$  is the coefficient matrix linking the covariates to the latent variables.

### Type 2:

The measurement model is given by

$$\mathbf{y}_t = \boldsymbol{\nu} + \mathbf{\Lambda}\boldsymbol{\eta}_t + \boldsymbol{\Gamma}_y \mathbf{x}_t + \boldsymbol{\varepsilon}_t \quad \text{with} \quad \boldsymbol{\varepsilon}_t \sim \mathcal{N}(\mathbf{0}, \boldsymbol{\Theta})$$

where  $\boldsymbol{\Gamma}_y$  is the coefficient matrix linking the covariates to the observed variables.

The dynamic structure is given by

$$\boldsymbol{\eta}_t = \boldsymbol{\alpha} + \boldsymbol{\beta}\boldsymbol{\eta}_{t-1} + \boldsymbol{\Gamma}_\eta \mathbf{x}_t + \boldsymbol{\zeta}_t \quad \text{with} \quad \boldsymbol{\zeta}_t \sim \mathcal{N}(\mathbf{0}, \boldsymbol{\Psi}).$$

## Value

Returns a list with the following elements:

- call: Function call.
- args: Function arguments.
- data: Generated data which is a list of length n.
- fun: Function used.

data is a list with the following elements:

- id: A vector of ones.
- time: A vector of discrete time points from 0 to  $t - 1$ .
- y: A  $t$  by  $k$  matrix of values for the manifest variables.
- eta: A  $t$  by  $p$  matrix of values for the latent variables.
- x: A  $t$  by  $j$  matrix of values for the covariates.

## References

Chow, S.-M., Ho, M. R., Hamaker, E. L., & Dolan, C. V. (2010). Equivalence and differences between structural equation modeling and state-space modeling techniques. *Structural Equation Modeling: A Multidisciplinary Journal*, 17(2), 303–332. doi:10.1080/10705511003661553

## See Also

Other Simulation of State Space Models Data Functions: [OU2SSM\(\)](#), [SimSSMFixed\(\)](#), [SimSSMIVary\(\)](#), [SimSSMLinGrowthIVary\(\)](#), [SimSSMLinGrowth\(\)](#), [SimSSMOUFixed\(\)](#), [SimSSMOUIVary\(\)](#), [SimSSMOU\(\)](#), [SimSSMVARFixed\(\)](#), [SimSSMVARIVary\(\)](#), [SimSSMVAR\(\)](#)

## Examples

```
# prepare parameters
set.seed(42)
k <- p <- 3
iden <- diag(k)
null_vec <- rep(x = 0, times = k)
mu0 <- null_vec
sigma0 <- iden
alpha <- null_vec
beta <- diag(x = 0.50, nrow = k)
psi <- iden
nu <- null_vec
lambda <- iden
theta <- diag(x = 0.50, nrow = k)
time <- 50
burn_in <- 0
gamma_y <- gamma_eta <- 0.10 * diag(k)
x <- matrix(
  data = rnorm(n = k * (time + burn_in)),
  ncol = k
)

# Type 0
SimSSM(
  mu0 = mu0,
  sigma0 = sigma0,
  alpha = alpha,
  beta = beta,
  psi = psi,
  nu = nu,
```

```

    lambda = lambda,
    theta = theta,
    type = 0,
    time = time,
    burn_in = burn_in
)

# Type 1
SimSSM(
  mu0 = mu0,
  sigma0 = sigma0,
  alpha = alpha,
  beta = beta,
  psi = psi,
  nu = nu,
  lambda = lambda,
  theta = theta,
  gamma_eta = gamma_eta,
  x = x,
  type = 1,
  time = time,
  burn_in = burn_in
)

# Type 2
SimSSM(
  mu0 = mu0,
  sigma0 = sigma0,
  alpha = alpha,
  beta = beta,
  psi = psi,
  nu = nu,
  lambda = lambda,
  theta = theta,
  gamma_y = gamma_y,
  gamma_eta = gamma_eta,
  x = x,
  type = 2,
  time = time,
  burn_in = burn_in
)

```

---

SimSSMFixed

*Simulate Data using a State Space Model Parameterization for  $n > 1$  Individuals (Fixed Parameters)*

---

### Description

This function simulates data using a state space model parameterization for  $n > 1$  individuals. In this model, the parameters are invariant across individuals.

**Usage**

```

SimSSMFixed(
  n,
  mu0,
  sigma0,
  alpha,
  beta,
  psi,
  nu,
  lambda,
  theta,
  gamma_y = NULL,
  gamma_eta = NULL,
  x = NULL,
  type = 0,
  time,
  burn_in = 0
)

```

**Arguments**

n	Positive integer. Number of individuals.
mu0	Numeric vector. Mean of initial latent variable values ( $\mu_{\eta 0}$ ).
sigma0	Numeric matrix. The covariance matrix of initial latent variable values ( $\Sigma_{\eta 0}$ ).
alpha	Numeric vector. Vector of intercepts for the dynamic model ( $\alpha$ ).
beta	Numeric matrix. Transition matrix relating the values of the latent variables at time $t - 1$ to those at time $t$ ( $\beta$ ).
psi	Numeric matrix. The process noise covariance matrix ( $\Psi$ ).
nu	Numeric vector. Vector of intercepts for the measurement model ( $\nu$ ).
lambda	Numeric matrix. Factor loading matrix linking the latent variables to the observed variables ( $\Lambda$ ).
theta	Numeric matrix. The measurement error covariance matrix ( $\Theta$ ).
gamma_y	Numeric matrix. Matrix relating the values of the covariate matrix at time $t$ to the observed variables at time $t$ ( $\Gamma_y$ ).
gamma_eta	Numeric matrix. Matrix relating the values of the covariate matrix at time $t$ to the latent variables at time $t$ ( $\Gamma_\eta$ ).
x	A list of length $n$ of numeric matrices. Each element of the list is a matrix of observed covariates in $\text{type} = 1$ or $\text{type} = 2$ . The number of rows in each matrix should be equal to $\text{time} + \text{burn\_in}$ .
type	Integer. State space model type.
time	Positive integer. Number of time points to simulate.
burn_in	Positive integer. Number of burn-in points to exclude before returning the results.

## Details

### Type 0:

The measurement model is given by

$$\mathbf{y}_{i,t} = \boldsymbol{\nu} + \mathbf{\Lambda}\boldsymbol{\eta}_{i,t} + \boldsymbol{\varepsilon}_{i,t} \quad \text{with} \quad \boldsymbol{\varepsilon}_{i,t} \sim \mathcal{N}(\mathbf{0}, \boldsymbol{\Theta})$$

where  $\mathbf{y}_{i,t}$ ,  $\boldsymbol{\eta}_{i,t}$ , and  $\boldsymbol{\varepsilon}_{i,t}$  are random variables and  $\boldsymbol{\nu}$ ,  $\mathbf{\Lambda}$ , and  $\boldsymbol{\Theta}$  are model parameters.  $\mathbf{y}_{i,t}$  is a vector of observed random variables,  $\boldsymbol{\eta}_{i,t}$  is a vector of latent random variables, and  $\boldsymbol{\varepsilon}_{i,t}$  is a vector of random measurement errors, at time  $t$  and individual  $i$ .  $\boldsymbol{\nu}$  is a vector of intercepts,  $\mathbf{\Lambda}$  is a matrix of factor loadings, and  $\boldsymbol{\Theta}$  is the covariance matrix of  $\boldsymbol{\varepsilon}$ .

The dynamic structure is given by

$$\boldsymbol{\eta}_{i,t} = \boldsymbol{\alpha} + \boldsymbol{\beta}\boldsymbol{\eta}_{i,t-1} + \boldsymbol{\zeta}_{i,t} \quad \text{with} \quad \boldsymbol{\zeta}_{i,t} \sim \mathcal{N}(\mathbf{0}, \boldsymbol{\Psi})$$

where  $\boldsymbol{\eta}_{i,t}$ ,  $\boldsymbol{\eta}_{i,t-1}$ , and  $\boldsymbol{\zeta}_{i,t}$  are random variables, and  $\boldsymbol{\alpha}$ ,  $\boldsymbol{\beta}$ , and  $\boldsymbol{\Psi}$  are model parameters.  $\boldsymbol{\eta}_{i,t}$  is a vector of latent variables at time  $t$  and individual  $i$ ,  $\boldsymbol{\eta}_{i,t-1}$  is a vector of latent variables at time  $t-1$  and individual  $i$ , and  $\boldsymbol{\zeta}_{i,t}$  is a vector of dynamic noise at time  $t$  and individual  $i$ .  $\boldsymbol{\alpha}$  is a vector of intercepts,  $\boldsymbol{\beta}$  is a matrix of autoregression and cross regression coefficients, and  $\boldsymbol{\Psi}$  is the covariance matrix of  $\boldsymbol{\zeta}_{i,t}$ .

### Type 1:

The measurement model is given by

$$\mathbf{y}_{i,t} = \boldsymbol{\nu} + \mathbf{\Lambda}\boldsymbol{\eta}_{i,t} + \boldsymbol{\varepsilon}_{i,t} \quad \text{with} \quad \boldsymbol{\varepsilon}_{i,t} \sim \mathcal{N}(\mathbf{0}, \boldsymbol{\Theta}).$$

The dynamic structure is given by

$$\boldsymbol{\eta}_{i,t} = \boldsymbol{\alpha} + \boldsymbol{\beta}\boldsymbol{\eta}_{i,t-1} + \boldsymbol{\Gamma}_{\boldsymbol{\eta}}\mathbf{x}_{i,t} + \boldsymbol{\zeta}_{i,t} \quad \text{with} \quad \boldsymbol{\zeta}_{i,t} \sim \mathcal{N}(\mathbf{0}, \boldsymbol{\Psi})$$

where  $\mathbf{x}_{i,t}$  is a vector of covariates at time  $t$  and individual  $i$ , and  $\boldsymbol{\Gamma}_{\boldsymbol{\eta}}$  is the coefficient matrix linking the covariates to the latent variables.

### Type 2:

The measurement model is given by

$$\mathbf{y}_{i,t} = \boldsymbol{\nu} + \mathbf{\Lambda}\boldsymbol{\eta}_{i,t} + \boldsymbol{\Gamma}_{\mathbf{y}}\mathbf{x}_{i,t} + \boldsymbol{\varepsilon}_{i,t} \quad \text{with} \quad \boldsymbol{\varepsilon}_{i,t} \sim \mathcal{N}(\mathbf{0}, \boldsymbol{\Theta})$$

where  $\boldsymbol{\Gamma}_{\mathbf{y}}$  is the coefficient matrix linking the covariates to the observed variables.

The dynamic structure is given by

$$\boldsymbol{\eta}_{i,t} = \boldsymbol{\alpha} + \boldsymbol{\beta}\boldsymbol{\eta}_{i,t-1} + \boldsymbol{\Gamma}_{\boldsymbol{\eta}}\mathbf{x}_{i,t} + \boldsymbol{\zeta}_{i,t} \quad \text{with} \quad \boldsymbol{\zeta}_{i,t} \sim \mathcal{N}(\mathbf{0}, \boldsymbol{\Psi}).$$

## Value

Returns a list with the following elements:

- call: Function call.
- args: Function arguments.
- data: Generated data which is a list of length n.
- fun: Function used.

Each element of data is a list with the following elements:

- id: A vector of ID numbers of length  $t$ .
- time: A vector of discrete time points from 0 to  $t - 1$ .
- y: A  $t$  by  $k$  matrix of values for the manifest variables.
- eta: A  $t$  by  $p$  matrix of values for the latent variables.
- x: A  $t$  by  $j$  matrix of values for the covariates.

### Author(s)

Ivan Jacob Agaloos Pesigan

### References

Chow, S.-M., Ho, M. R., Hamaker, E. L., & Dolan, C. V. (2010). Equivalence and differences between structural equation modeling and state-space modeling techniques. *Structural Equation Modeling: A Multidisciplinary Journal*, 17(2), 303–332. doi:10.1080/10705511003661553

### See Also

Other Simulation of State Space Models Data Functions: [OU2SSM\(\)](#), [SimSSMIVary\(\)](#), [SimSSMLinGrowthIVary\(\)](#), [SimSSMLinGrowth\(\)](#), [SimSSMOUFixed\(\)](#), [SimSSMOUIVary\(\)](#), [SimSSMOU\(\)](#), [SimSSMVARFixed\(\)](#), [SimSSMVARIVary\(\)](#), [SimSSMVAR\(\)](#), [SimSSM\(\)](#)

### Examples

```
# prepare parameters
set.seed(42)
k <- p <- 3
iden <- diag(k)
null_vec <- rep(x = 0, times = k)
n <- 5
mu0 <- null_vec
sigma0 <- iden
alpha <- null_vec
beta <- diag(x = 0.50, nrow = k)
psi <- iden
nu <- null_vec
lambda <- iden
theta <- diag(x = 0.50, nrow = k)
time <- 50
burn_in <- 0
gamma_y <- gamma_eta <- 0.10 * diag(k)
x <- lapply(
  X = seq_len(n),
  FUN = function(i) {
    return(
      matrix(
        data = rnorm(n = k * (time + burn_in)),
        ncol = k
      )
    )
  }
)
```



```

    )
  }
)

# Type 0
SimSSMFixed(
  n = n,
  mu0 = mu0,
  sigma0 = sigma0,
  alpha = alpha,
  beta = beta,
  psi = psi,
  nu = nu,
  lambda = lambda,
  theta = theta,
  type = 0,
  time = time,
  burn_in = burn_in
)

# Type 1
SimSSMFixed(
  n = n,
  mu0 = mu0,
  sigma0 = sigma0,
  alpha = alpha,
  beta = beta,
  psi = psi,
  nu = nu,
  lambda = lambda,
  theta = theta,
  gamma_eta = gamma_eta,
  x = x,
  type = 1,
  time = time,
  burn_in = burn_in
)

# Type 2
SimSSMFixed(
  n = n,
  mu0 = mu0,
  sigma0 = sigma0,
  alpha = alpha,
  beta = beta,
  psi = psi,
  nu = nu,
  lambda = lambda,
  theta = theta,
  gamma_y = gamma_y,
  gamma_eta = gamma_eta,
  x = x,
  type = 2,

```

```

    time = time,
    burn_in = burn_in
  )

```

---

SimSSMIVary

*Simulate Data using a State Space Model Parameterization for  $n > 1$  Individuals (Individual-Varying Parameters)*

---

## Description

This function simulates data using a state space model parameterization for  $n > 1$  individuals. In this model, the parameters can vary across individuals.

## Usage

```

SimSSMIVary(
  n,
  mu0,
  sigma0,
  alpha,
  beta,
  psi,
  nu,
  lambda,
  theta,
  gamma_y = NULL,
  gamma_eta = NULL,
  x = NULL,
  type,
  time = 0,
  burn_in = 0
)

```

## Arguments

n	Positive integer. Number of individuals.
mu0	List of numeric vectors. Each element of the list is the mean of initial latent variable values ( $\mu_{\eta 0}$ ).
sigma0	List of numeric matrices. Each element of the list is the covariance matrix of initial latent variable values ( $\Sigma_{\eta 0}$ ).
alpha	List of numeric vectors. Each element of the list is the vector of intercepts for the dynamic model ( $\alpha$ ).
beta	List of numeric matrices. Each element of the list is the transition matrix relating the values of the latent variables at time $t - 1$ to those at time $t$ ( $\beta$ ).

psi	List of numeric matrices. Each element of the list is the process noise covariance matrix ( $\Psi$ ).
nu	List of numeric vectors. Each element of the list is the vector of intercepts for the measurement model ( $\nu$ ).
lambda	List of numeric matrices. Each element of the list is the factor loading matrix linking the latent variables to the observed variables ( $\Lambda$ ).
theta	List of numeric matrices. Each element of the list is the measurement error covariance matrix ( $\Theta$ ).
gamma_y	Numeric matrix. Matrix relating the values of the covariate matrix at time $t$ to the observed variables at time $t$ ( $\Gamma_y$ ).
gamma_eta	Numeric matrix. Matrix relating the values of the covariate matrix at time $t$ to the latent variables at time $t$ ( $\Gamma_\eta$ ).
x	A list of length $n$ of numeric matrices. Each element of the list is a matrix of observed covariates in type = 1 or type = 2. The number of rows in each matrix should be equal to time + burn_in.
type	Integer. State space model type.
time	Positive integer. Number of time points to simulate.
burn_in	Positive integer. Number of burn-in points to exclude before returning the results.

### Details

Parameters can vary across individuals by providing a list of parameter values. If the length of any of the parameters ( $\mu_0$ ,  $\sigma_0$ ,  $\alpha$ ,  $\beta$ ,  $\psi$ ,  $\nu$ ,  $\lambda$ ,  $\theta$ ,  $\gamma_y$ , or  $\gamma_\eta$ ) is less than  $n$ , the function will cycle through the available values.

### Value

Returns a list with the following elements:

- call: Function call.
- args: Function arguments.
- data: Generated data which is a list of length  $n$ .
- fun: Function used.

Each element of data is a list with the following elements:

- id: A vector of ID numbers of length  $t$ .
- time: A vector of discrete time points from 0 to  $t - 1$ .
- y: A  $t$  by  $k$  matrix of values for the manifest variables.
- eta: A  $t$  by  $p$  matrix of values for the latent variables.
- x: A  $t$  by  $j$  matrix of values for the covariates.

### Author(s)

Ivan Jacob Agaloos Pesigan

## References

Chow, S.-M., Ho, M. R., Hamaker, E. L., & Dolan, C. V. (2010). Equivalence and differences between structural equation modeling and state-space modeling techniques. *Structural Equation Modeling: A Multidisciplinary Journal*, 17(2), 303–332. doi:10.1080/10705511003661553

## See Also

Other Simulation of State Space Models Data Functions: [OU2SSM\(\)](#), [SimSSMFixed\(\)](#), [SimSSMLinGrowthIVary\(\)](#), [SimSSMLinGrowth\(\)](#), [SimSSMOUFixed\(\)](#), [SimSSMOUIVary\(\)](#), [SimSSMOU\(\)](#), [SimSSMVARFixed\(\)](#), [SimSSMVARIVary\(\)](#), [SimSSMVAR\(\)](#), [SimSSM\(\)](#)

## Examples

```
# prepare parameters
# In this example, beta varies across individuals
set.seed(42)
k <- p <- 3
iden <- diag(k)
null_vec <- rep(x = 0, times = k)
n <- 5
mu0 <- list(null_vec)
sigma0 <- list(iden)
alpha <- list(null_vec)
beta <- list(
  diag(x = 0.1, nrow = k),
  diag(x = 0.2, nrow = k),
  diag(x = 0.3, nrow = k),
  diag(x = 0.4, nrow = k),
  diag(x = 0.5, nrow = k)
)
psi <- list(iden)
nu <- list(null_vec)
lambda <- list(iden)
theta <- list(diag(x = 0.50, nrow = k))
time <- 50
burn_in <- 0
gamma_y <- gamma_eta <- list(0.10 * diag(k))
x <- lapply(
  X = seq_len(n),
  FUN = function(i) {
    return(
      matrix(
        data = rnorm(n = k * (time + burn_in)),
        ncol = k
      )
    )
  }
)

# Type 0
SimSSMIVary(
  n = n,
```

```
mu0 = mu0,  
sigma0 = sigma0,  
alpha = alpha,  
beta = beta,  
psi = psi,  
nu = nu,  
lambda = lambda,  
theta = theta,  
type = 0,  
time = time,  
burn_in = burn_in  
)
```

```
# Type 1  
SimSSMIVary(  
  n = n,  
  mu0 = mu0,  
  sigma0 = sigma0,  
  alpha = alpha,  
  beta = beta,  
  psi = psi,  
  nu = nu,  
  lambda = lambda,  
  theta = theta,  
  gamma_eta = gamma_eta,  
  x = x,  
  type = 1,  
  time = time,  
  burn_in = burn_in  
)
```

```
# Type 2  
SimSSMIVary(  
  n = n,  
  mu0 = mu0,  
  sigma0 = sigma0,  
  alpha = alpha,  
  beta = beta,  
  psi = psi,  
  nu = nu,  
  lambda = lambda,  
  theta = theta,  
  gamma_y = gamma_y,  
  gamma_eta = gamma_eta,  
  x = x,  
  type = 2,  
  time = time,  
  burn_in = burn_in  
)
```

SimSSMLinGrowth

*Simulate Data from a Linear Growth Curve Model***Description**

This function simulates data from a linear growth curve model for  $n > 1$  individuals.

**Usage**

```
SimSSMLinGrowth(
  n,
  mu0,
  sigma0,
  theta,
  gamma_y = NULL,
  gamma_eta = NULL,
  x = NULL,
  type = 0,
  time
)
```

**Arguments**

n	Positive integer. Number of individuals.
mu0	Numeric vector. A vector of length two. The first element is the mean of the intercept, and the second element is the mean of the slope.
sigma0	Numeric matrix. The covariance matrix of the intercept and the slope.
theta	Numeric. The common measurement error variance.
gamma_y	Numeric matrix. Matrix relating the values of the covariate matrix at time t to y at time t ( $\Gamma_y$ ).
gamma_eta	Numeric matrix. Matrix relating the values of the covariate matrix at time t to the latent variables (intercept and slope) at time t ( $\Gamma_\eta$ ).
x	A list of length n of numeric matrices. Each element of the list is a matrix of observed covariates in type = 1 or type = 2. The number of rows in each matrix should be equal to time.
type	Integer. State space model type.
time	Positive integer. Number of time points to simulate.

**Details****Type 0:**

The measurement model is given by

$$y_{i,t} = \begin{pmatrix} 1 & 0 \end{pmatrix} \begin{pmatrix} \eta_{0,i,t} \\ \eta_{1,i,t} \end{pmatrix} + \varepsilon_{i,t} \quad \text{with} \quad \varepsilon_{i,t} \sim \mathcal{N}(0, \theta)$$

where  $y_{i,t}$ ,  $\eta_{0i,t}$ ,  $\eta_{1i,t}$ , and  $\varepsilon_{i,t}$  are random variables and  $\theta$  is a model parameter.  $y_{i,t}$  is a vector of observed random variables at time  $t$  and individual  $i$ ,  $\eta_{0i,t}$  and  $\eta_{1i,t}$  form a vector of latent random variables at time  $t$  and individual  $i$ , and  $\varepsilon_{i,t}$  is a vector of random measurement errors at time  $t$  and individual  $i$ .  $\theta$  is the variance of  $\varepsilon$ .

The dynamic structure is given by

$$\begin{pmatrix} \eta_{0i,t} \\ \eta_{1i,t} \end{pmatrix} = \begin{pmatrix} 1 & 1 \\ 0 & 1 \end{pmatrix} \begin{pmatrix} \eta_{0i,t-1} \\ \eta_{1i,t-1} \end{pmatrix}.$$

The mean vector and covariance matrix of the intercept and slope are captured in the mean vector and covariance matrix of the initial condition given by

$$\begin{aligned} \boldsymbol{\mu}_{\boldsymbol{\eta}|0} &= \begin{pmatrix} \mu_{\eta_0} \\ \mu_{\eta_1} \end{pmatrix} \quad \text{and,} \\ \boldsymbol{\Sigma}_{\boldsymbol{\eta}|0} &= \begin{pmatrix} \sigma_{\eta_0}^2 & \sigma_{\eta_0, \eta_1} \\ \sigma_{\eta_1, \eta_0} & \sigma_{\eta_1}^2 \end{pmatrix}. \end{aligned}$$

#### Type 1:

The measurement model is given by

$$y_{i,t} = \begin{pmatrix} 1 & 0 \end{pmatrix} \begin{pmatrix} \eta_{0i,t} \\ \eta_{1i,t} \end{pmatrix} + \varepsilon_{i,t} \quad \text{with} \quad \varepsilon_{i,t} \sim \mathcal{N}(0, \theta).$$

The dynamic structure is given by

$$\begin{pmatrix} \eta_{0i,t} \\ \eta_{1i,t} \end{pmatrix} = \begin{pmatrix} 1 & 1 \\ 0 & 1 \end{pmatrix} \begin{pmatrix} \eta_{0i,t-1} \\ \eta_{1i,t-1} \end{pmatrix} + \boldsymbol{\Gamma}_{\boldsymbol{\eta}} \mathbf{x}_{i,t}$$

where  $\mathbf{x}_{i,t}$  is a vector of covariates at time  $t$  and individual  $i$ , and  $\boldsymbol{\Gamma}_{\boldsymbol{\eta}}$  is the coefficient matrix linking the covariates to the latent variables.

#### Type 2:

The measurement model is given by

$$y_{i,t} = \begin{pmatrix} 1 & 0 \end{pmatrix} \begin{pmatrix} \eta_{0i,t} \\ \eta_{1i,t} \end{pmatrix} + \boldsymbol{\Gamma}_{\mathbf{y}} \mathbf{x}_{i,t} + \varepsilon_{i,t} \quad \text{with} \quad \varepsilon_{i,t} \sim \mathcal{N}(0, \theta)$$

where  $\boldsymbol{\Gamma}_{\mathbf{y}}$  is the coefficient matrix linking the covariates to the observed variables.

The dynamic structure is given by

$$\begin{pmatrix} \eta_{0i,t} \\ \eta_{1i,t} \end{pmatrix} = \begin{pmatrix} 1 & 1 \\ 0 & 1 \end{pmatrix} \begin{pmatrix} \eta_{0i,t-1} \\ \eta_{1i,t-1} \end{pmatrix} + \boldsymbol{\Gamma}_{\boldsymbol{\eta}} \mathbf{x}_{i,t}.$$

#### Value

Returns a list with the following elements:

- call: Function call.
- args: Function arguments.

- data: Generated data which is a list of length n.
- fun: Function used.

Each element of data is a list with the following elements:

- id: A vector of ID numbers of length t.
- time: A vector of discrete time points from 0 to t - 1.
- y: A t by k matrix of values for the manifest variables.
- eta: A t by p matrix of values for the latent variables.
- x: A t by j matrix of values for the covariates.

### Author(s)

Ivan Jacob Agaloos Pesigan

### References

Chow, S.-M., Ho, M. R., Hamaker, E. L., & Dolan, C. V. (2010). Equivalence and differences between structural equation modeling and state-space modeling techniques. *Structural Equation Modeling: A Multidisciplinary Journal*, 17(2), 303–332. doi:10.1080/10705511003661553

### See Also

Other Simulation of State Space Models Data Functions: [OU2SSM\(\)](#), [SimSSMFixed\(\)](#), [SimSSMIVary\(\)](#), [SimSSMLinGrowthIVary\(\)](#), [SimSSMOUFixed\(\)](#), [SimSSMOUIVary\(\)](#), [SimSSMOU\(\)](#), [SimSSMVARFixed\(\)](#), [SimSSMVARIVary\(\)](#), [SimSSMVAR\(\)](#), [SimSSM\(\)](#)

### Examples

```
# prepare parameters
set.seed(42)
n <- 10
mu0 <- c(0.615, 1.006)
sigma0 <- matrix(
  data = c(
    1.932,
    0.618,
    0.618,
    0.587
  ),
  nrow = 2
)
theta <- 0.6
time <- 10
gamma_y <- matrix(data = 0.10, nrow = 1, ncol = 2)
gamma_eta <- matrix(data = 0.10, nrow = 2, ncol = 2)
x <- lapply(
  X = seq_len(n),
  FUN = function(i) {
    return(
```



```

        matrix(
          data = rnorm(n = 2 * time),
          ncol = 2
        )
      )
    }
  )

# Type 0
SimSSMLinGrowth(
  n = n,
  mu0 = mu0,
  sigma0 = sigma0,
  theta = theta,
  type = 0,
  time = time
)

# Type 1
SimSSMLinGrowth(
  n = n,
  mu0 = mu0,
  sigma0 = sigma0,
  theta = theta,
  gamma_eta = gamma_eta,
  x = x,
  type = 1,
  time = time
)

# Type 2
SimSSMLinGrowth(
  n = n,
  mu0 = mu0,
  sigma0 = sigma0,
  theta = theta,
  gamma_y = gamma_y,
  gamma_eta = gamma_eta,
  x = x,
  type = 2,
  time = time
)

```

## Description

This function simulates data from a linear growth curve model for  $n > 1$  individuals. In this model, the parameters can vary across individuals.

## Usage

```
SimSSMLinGrowthIVary(
  n,
  mu0,
  sigma0,
  theta,
  gamma_y = NULL,
  gamma_eta = NULL,
  x = NULL,
  type = 0,
  time
)
```

## Arguments

n	Positive integer. Number of individuals.
mu0	A list of numeric vectors. Each element of the list is a vector of length two. The first element is the mean of the intercept, and the second element is the mean of the slope.
sigma0	A list of numeric matrices. Each element of the list is the covariance matrix of the intercept and the slope.
theta	A list numeric values. Each element of the list is the common measurement error variance.
gamma_y	Numeric matrix. Matrix relating the values of the covariate matrix at time $t$ to $y$ at time $t$ ( $\Gamma_y$ ).
gamma_eta	Numeric matrix. Matrix relating the values of the covariate matrix at time $t$ to the latent variables (intercept and slope) at time $t$ ( $\Gamma_\eta$ ).
x	A list of length $n$ of numeric matrices. Each element of the list is a matrix of observed covariates in $\text{type} = 1$ or $\text{type} = 2$ . The number of rows in each matrix should be equal to $\text{time}$ .
type	Integer. State space model type.
time	Positive integer. Number of time points to simulate.

## Details

Parameters can vary across individuals by providing a list of parameter values. If the length of any of the parameters ( $\text{mu0}$ ,  $\text{sigma0}$ ,  $\text{mu}$ ,  $\text{theta}$ ,  $\text{gamma\_y}$ , or  $\text{gamma\_eta}$ ) is less than  $n$ , the function will cycle through the available values.

**Value**

Returns a list with the following elements:

- call: Function call.
- args: Function arguments.
- data: Generated data which is a list of length n.
- fun: Function used.

Each element of data is a list with the following elements:

- id: A vector of ID numbers of length t.
- time: A vector of discrete time points from 0 to t - 1.
- y: A t by k matrix of values for the manifest variables.
- eta: A t by p matrix of values for the latent variables.
- x: A t by j matrix of values for the covariates.

**Author(s)**

Ivan Jacob Agaloos Pesigan

**References**

Chow, S.-M., Ho, M. R., Hamaker, E. L., & Dolan, C. V. (2010). Equivalence and differences between structural equation modeling and state-space modeling techniques. *Structural Equation Modeling: A Multidisciplinary Journal*, 17(2), 303–332. doi:10.1080/10705511003661553

**See Also**

Other Simulation of State Space Models Data Functions: [OU2SSM\(\)](#), [SimSSMFixed\(\)](#), [SimSSMIVary\(\)](#), [SimSSMLinGrowth\(\)](#), [SimSSMOUFixed\(\)](#), [SimSSMOUIVary\(\)](#), [SimSSMOU\(\)](#), [SimSSMVARFixed\(\)](#), [SimSSMVARIVary\(\)](#), [SimSSMVAR\(\)](#), [SimSSM\(\)](#)

**Examples**

```
# prepare parameters
# In this example, the mean vector of the intercept and slope vary.
# Specifically,
# there are two sets of values representing two latent classes.
set.seed(42)
n <- 10
mu0_1 <- c(0.615, 1.006) # lower starting point, higher growth
mu0_2 <- c(1.000, 0.500) # higher starting point, lower growth
mu0 <- list(mu0_1, mu0_2)
sigma0 <- list(
  matrix(
    data = c(
      1.932,
      0.618,
      0.618,
```

```

        0.587
      ),
      nrow = 2
    )
  )
  theta <- list(0.6)
  time <- 10
  gamma_y <- list(matrix(data = 0.10, nrow = 1, ncol = 2))
  gamma_eta <- list(matrix(data = 0.10, nrow = 2, ncol = 2))
  x <- lapply(
    X = seq_len(n),
    FUN = function(i) {
      return(
        matrix(
          data = rnorm(n = 2 * time),
          ncol = 2
        )
      )
    }
  )
)

# Type 0
SimSSMLinGrowthIVary(
  n = n,
  mu0 = mu0,
  sigma0 = sigma0,
  theta = theta,
  type = 0,
  time = time
)

# Type 1
SimSSMLinGrowthIVary(
  n = n,
  mu0 = mu0,
  sigma0 = sigma0,
  theta = theta,
  gamma_eta = gamma_eta,
  x = x,
  type = 1,
  time = time
)

# Type 2
SimSSMLinGrowthIVary(
  n = n,
  mu0 = mu0,
  sigma0 = sigma0,
  theta = theta,
  gamma_y = gamma_y,
  gamma_eta = gamma_eta,
  x = x,
  type = 2,

```

```

    time = time
)

```

SimSSMOU

*Simulate Data from the Ornstein–Uhlenbeck Model using a State Space Model Parameterization ( $n = 1$ )*

## Description

This function simulates data from the Ornstein–Uhlenbeck model using a state space model parameterization. See details for more information.

## Usage

```

SimSSMOU(
  mu0,
  sigma0,
  mu,
  phi,
  sigma,
  nu,
  lambda,
  theta,
  gamma_y = NULL,
  gamma_eta = NULL,
  x = NULL,
  type = 0,
  delta_t,
  time,
  burn_in = 0
)

```

## Arguments

mu0	Numeric vector. Mean of initial latent variable values ( $\mu_{\eta 0}$ ).
sigma0	Numeric matrix. The covariance matrix of initial latent variable values ( $\Sigma_{\eta 0}$ ).
mu	Numeric vector. The long-term mean or equilibrium level ( $\mu$ ).
phi	Numeric matrix. The rate of mean reversion, determining how quickly the variable returns to its mean ( $\Phi$ ).
sigma	Numeric matrix. The matrix of volatility or randomness in the process ( $\Sigma$ ).
nu	Numeric vector. Vector of intercepts for the measurement model ( $\nu$ ).
lambda	Numeric matrix. Factor loading matrix linking the latent variables to the observed variables ( $\Lambda$ ).
theta	Numeric matrix. The measurement error covariance matrix ( $\Theta$ ).

gamma_y	Numeric matrix. Matrix relating the values of the covariate matrix at time $t$ to the observed variables at time $t$ ( $\Gamma_y$ ).
gamma_eta	Numeric matrix. Matrix relating the values of the covariate matrix at time $t$ to the latent variables at time $t$ ( $\Gamma_\eta$ ).
x	Numeric matrix. The matrix of observed covariates in <code>type = 1</code> or <code>type = 2</code> . The number of rows should be equal to <code>time + burn_in</code> .
type	Integer. State space model type.
delta_t	Numeric. Time interval ( $\delta_t$ ).
time	Positive integer. Number of time points to simulate.
burn_in	Positive integer. Number of burn-in points to exclude before returning the results.

### Details

#### Type 0:

The measurement model is given by

$$\mathbf{y}_t = \boldsymbol{\nu} + \boldsymbol{\Lambda}\boldsymbol{\eta}_t + \boldsymbol{\varepsilon}_t \quad \text{with} \quad \boldsymbol{\varepsilon}_t \sim \mathcal{N}(\mathbf{0}, \boldsymbol{\Theta})$$

where  $\mathbf{y}_t$ ,  $\boldsymbol{\eta}_t$ , and  $\boldsymbol{\varepsilon}_t$  are random variables and  $\boldsymbol{\nu}$ ,  $\boldsymbol{\Lambda}$ , and  $\boldsymbol{\Theta}$  are model parameters.  $\mathbf{y}_t$  is a vector of observed random variables,  $\boldsymbol{\eta}_t$  is a vector of latent random variables, and  $\boldsymbol{\varepsilon}_t$  is a vector of random measurement errors, at time  $t$ .  $\boldsymbol{\nu}$  is a vector of intercepts,  $\boldsymbol{\Lambda}$  is a matrix of factor loadings, and  $\boldsymbol{\Theta}$  is the covariance matrix of  $\boldsymbol{\varepsilon}$ .

The dynamic structure is given by

$$d\boldsymbol{\eta}_t = \boldsymbol{\Phi}(\boldsymbol{\mu} - \boldsymbol{\eta}_t)dt + \boldsymbol{\Sigma}^{\frac{1}{2}}d\mathbf{W}_t$$

where  $\boldsymbol{\mu}$  is the long-term mean or equilibrium level,  $\boldsymbol{\Phi}$  is the rate of mean reversion, determining how quickly the variable returns to its mean,  $\boldsymbol{\Sigma}$  is the matrix of volatility or randomness in the process, and  $d\mathbf{W}$  is a Wiener process or Brownian motion, which represents random fluctuations.

#### Type 1:

The measurement model is given by

$$\mathbf{y}_t = \boldsymbol{\nu} + \boldsymbol{\Lambda}\boldsymbol{\eta}_t + \boldsymbol{\varepsilon}_t \quad \text{with} \quad \boldsymbol{\varepsilon}_t \sim \mathcal{N}(\mathbf{0}, \boldsymbol{\Theta}).$$

The dynamic structure is given by

$$d\boldsymbol{\eta}_t = \boldsymbol{\Phi}(\boldsymbol{\mu} - \boldsymbol{\eta}_t)dt + \boldsymbol{\Gamma}_\eta \mathbf{x}_t + \boldsymbol{\Sigma}^{\frac{1}{2}}d\mathbf{W}_t$$

where  $\mathbf{x}_t$  is a vector of covariates at time  $t$ , and  $\boldsymbol{\Gamma}_\eta$  is the coefficient matrix linking the covariates to the latent variables.

#### Type 2:

The measurement model is given by

$$\mathbf{y}_t = \boldsymbol{\nu} + \boldsymbol{\Lambda}\boldsymbol{\eta}_t + \boldsymbol{\Gamma}_y \mathbf{x}_t + \boldsymbol{\varepsilon}_t \quad \text{with} \quad \boldsymbol{\varepsilon}_t \sim \mathcal{N}(\mathbf{0}, \boldsymbol{\Theta})$$

where  $\boldsymbol{\Gamma}_y$  is the coefficient matrix linking the covariates to the observed variables.

The dynamic structure is given by

$$d\boldsymbol{\eta}_t = \boldsymbol{\Phi}(\boldsymbol{\mu} - \boldsymbol{\eta}_t)dt + \boldsymbol{\Gamma}_\eta \mathbf{x}_t + \boldsymbol{\Sigma}^{\frac{1}{2}}d\mathbf{W}_t.$$

**Value**

Returns a list with the following elements:

- `y`: A `t` by `k` matrix of values for the manifest variables.
- `eta`: A `t` by `p` matrix of values for the latent variables.
- `time`: A vector of continuous time points of length `t` starting from 0 with `delta_t` increments.
- `id`: A vector of ones.

**Author(s)**

Ivan Jacob Agaloos Pesigan

**References**

Chow, S.-M., Losardo, D., Park, J., & Molenaar, P. C. M. (2023). Continuous-time dynamic models: Connections to structural equation models and other discrete-time models. In R. H. Hoyle (Ed.), *Handbook of structural equation modeling* (2nd ed.). The Guilford Press.

Uhlenbeck, G. E., & Ornstein, L. S. (1930). On the theory of the brownian motion. *Physical Review*, 36(5), 823–841. doi:10.1103/physrev.36.823

**See Also**

Other Simulation of State Space Models Data Functions: [OU2SSM\(\)](#), [SimSSMFixed\(\)](#), [SimSSMIVary\(\)](#), [SimSSMLinGrowthIVary\(\)](#), [SimSSMLinGrowth\(\)](#), [SimSSMOUFixed\(\)](#), [SimSSMOUIVary\(\)](#), [SimSSMVARFixed\(\)](#), [SimSSMVARIVary\(\)](#), [SimSSMVAR\(\)](#), [SimSSM\(\)](#)

**Examples**

```
# prepare parameters
set.seed(42)
p <- k <- 2
iden <- diag(p)
mu0 <- c(-3.0, 1.5)
sigma0 <- iden
mu <- c(5.76, 5.18)
phi <- matrix(data = c(0.10, -0.05, -0.05, 0.10), nrow = p)
sigma <- matrix(
  data = c(2.79, 0.06, 0.06, 3.27),
  nrow = p
)
nu <- rep(x = 0, times = k)
lambda <- diag(k)
theta <- diag(x = 0.50, nrow = k)
delta_t <- 0.10
time <- 50
burn_in <- 0
gamma_y <- gamma_eta <- 0.10 * diag(k)
x <- matrix(
  data = rnorm(n = k * (time + burn_in)),
  ncol = k
```

```
)

# Type 0
SimSSMOU(
  mu0 = mu0,
  sigma0 = sigma0,
  mu = mu,
  phi = phi,
  sigma = sigma,
  nu = nu,
  lambda = lambda,
  theta = theta,
  type = 0,
  delta_t = delta_t,
  time = time,
  burn_in = burn_in
)

# Type 1
SimSSMOU(
  mu0 = mu0,
  sigma0 = sigma0,
  mu = mu,
  phi = phi,
  sigma = sigma,
  nu = nu,
  lambda = lambda,
  theta = theta,
  gamma_eta = gamma_eta,
  x = x,
  type = 1,
  delta_t = delta_t,
  time = time,
  burn_in = burn_in
)

# Type 2
SimSSMOU(
  mu0 = mu0,
  sigma0 = sigma0,
  mu = mu,
  phi = phi,
  sigma = sigma,
  nu = nu,
  lambda = lambda,
  theta = theta,
  gamma_y = gamma_y,
  gamma_eta = gamma_eta,
  x = x,
  type = 2,
  delta_t = delta_t,
  time = time,
  burn_in = burn_in
)
```



)

SimSSMOUFixed

*Simulate Data from an Ornstein–Uhlenbeck Model using a State Space Model Parameterization for  $n > 1$  Individuals (Fixed Parameters)*

### Description

This function simulates data from an Ornstein–Uhlenbeck model using a state space model parameterization for  $n > 1$  individuals. In this model, the parameters are invariant across individuals. See details for more information.

### Usage

```
SimSSMOUFixed(
  n,
  mu0,
  sigma0,
  mu,
  phi,
  sigma,
  nu,
  lambda,
  theta,
  gamma_y = NULL,
  gamma_eta = NULL,
  x = NULL,
  type = 0,
  delta_t,
  time,
  burn_in = 0
)
```

### Arguments

n	Positive integer. Number of individuals.
mu0	Numeric vector. Mean of initial latent variable values ( $\mu_{\eta 0}$ ).
sigma0	Numeric matrix. The covariance matrix of initial latent variable values ( $\Sigma_{\eta 0}$ ).
mu	Numeric vector. The long-term mean or equilibrium level ( $\mu$ ).
phi	Numeric matrix. The rate of mean reversion, determining how quickly the variable returns to its mean ( $\Phi$ ).
sigma	Numeric matrix. The matrix of volatility or randomness in the process ( $\Sigma$ ).
nu	Numeric vector. Vector of intercepts for the measurement model ( $\nu$ ).

lambda	Numeric matrix. Factor loading matrix linking the latent variables to the observed variables ( $\Lambda$ ).
theta	Numeric matrix. The measurement error covariance matrix ( $\Theta$ ).
gamma_y	Numeric matrix. Matrix relating the values of the covariate matrix at time $t$ to the observed variables at time $t$ ( $\Gamma_y$ ).
gamma_eta	Numeric matrix. Matrix relating the values of the covariate matrix at time $t$ to the latent variables at time $t$ ( $\Gamma_\eta$ ).
x	Numeric matrix. The matrix of observed covariates in type = 1 or type = 2. The number of rows should be equal to time + burn_in.
type	Integer. State space model type.
delta_t	Numeric. Time interval ( $\delta_t$ ).
time	Positive integer. Number of time points to simulate.
burn_in	Positive integer. Number of burn-in points to exclude before returning the results.

## Details

### Type 0:

The measurement model is given by

$$\mathbf{y}_{i,t} = \boldsymbol{\nu} + \Lambda \boldsymbol{\eta}_{i,t} + \boldsymbol{\varepsilon}_{i,t} \quad \text{with} \quad \boldsymbol{\varepsilon}_{i,t} \sim \mathcal{N}(\mathbf{0}, \Theta)$$

where  $\mathbf{y}_{i,t}$ ,  $\boldsymbol{\eta}_{i,t}$ , and  $\boldsymbol{\varepsilon}_{i,t}$  are random variables and  $\boldsymbol{\nu}$ ,  $\Lambda$ , and  $\Theta$  are model parameters.  $\mathbf{y}_{i,t}$  is a vector of observed random variables,  $\boldsymbol{\eta}_{i,t}$  is a vector of latent random variables, and  $\boldsymbol{\varepsilon}_{i,t}$  is a vector of random measurement errors, at time  $t$  and individual  $i$ .  $\boldsymbol{\nu}$  is a vector of intercepts,  $\Lambda$  is a matrix of factor loadings, and  $\Theta$  is the covariance matrix of  $\boldsymbol{\varepsilon}$ .

The dynamic structure is given by

$$d\boldsymbol{\eta}_{i,t} = \Phi (\boldsymbol{\mu} - \boldsymbol{\eta}_{i,t}) dt + \Sigma^{\frac{1}{2}} d\mathbf{W}_{i,t}$$

where  $\boldsymbol{\mu}$  is the long-term mean or equilibrium level,  $\Phi$  is the rate of mean reversion, determining how quickly the variable returns to its mean,  $\Sigma$  is the matrix of volatility or randomness in the process, and  $d\mathbf{W}$  is a Wiener process or Brownian motion, which represents random fluctuations.

### Type 1:

The measurement model is given by

$$\mathbf{y}_{i,t} = \boldsymbol{\nu} + \Lambda \boldsymbol{\eta}_{i,t} + \boldsymbol{\varepsilon}_{i,t} \quad \text{with} \quad \boldsymbol{\varepsilon}_{i,t} \sim \mathcal{N}(\mathbf{0}, \Theta).$$

The dynamic structure is given by

$$d\boldsymbol{\eta}_{i,t} = \Phi (\boldsymbol{\mu} - \boldsymbol{\eta}_{i,t}) dt + \Gamma_\eta \mathbf{x}_{i,t} + \Sigma^{\frac{1}{2}} d\mathbf{W}_{i,t}$$

where  $\mathbf{x}_{i,t}$  is a vector of covariates at time  $t$  and individual  $i$ , and  $\Gamma_\eta$  is the coefficient matrix linking the covariates to the latent variables.

**Type 2:**

The measurement model is given by

$$\mathbf{y}_{i,t} = \boldsymbol{\nu} + \boldsymbol{\Lambda}\boldsymbol{\eta}_{i,t} + \boldsymbol{\Gamma}_y\mathbf{x}_{i,t} + \boldsymbol{\varepsilon}_{i,t} \quad \text{with} \quad \boldsymbol{\varepsilon}_{i,t} \sim \mathcal{N}(\mathbf{0}, \boldsymbol{\Theta})$$

where  $\boldsymbol{\Gamma}_y$  is the coefficient matrix linking the covariates to the observed variables.

The dynamic structure is given by

$$d\boldsymbol{\eta}_{i,t} = \boldsymbol{\Phi}(\boldsymbol{\mu} - \boldsymbol{\eta}_{i,t}) dt + \boldsymbol{\Gamma}_\eta\mathbf{x}_{i,t} + \boldsymbol{\Sigma}^{\frac{1}{2}}d\mathbf{W}_{i,t}.$$

**Value**

Returns a list of length n. Each element is a list with the following elements:

- y: A t by k matrix of values for the manifest variables.
- eta: A t by p matrix of values for the latent variables.
- x: A t by j matrix of values for the covariates.
- time: A vector of continuous time points of length t starting from 0 with delta\_t increments.
- id: A vector of ID numbers of length t.
- n: Number of individuals.

**Author(s)**

Ivan Jacob Agaloos Pesigan

**References**

Chow, S.-M., Losardo, D., Park, J., & Molenaar, P. C. M. (2023). Continuous-time dynamic models: Connections to structural equation models and other discrete-time models. In R. H. Hoyle (Ed.), *Handbook of structural equation modeling* (2nd ed.). The Guilford Press.

Uhlenbeck, G. E., & Ornstein, L. S. (1930). On the theory of the brownian motion. *Physical Review*, 36(5), 823–841. doi:10.1103/physrev.36.823

**See Also**

Other Simulation of State Space Models Data Functions: [OU2SSM\(\)](#), [SimSSMFixed\(\)](#), [SimSSMIVary\(\)](#), [SimSSMLinGrowthIVary\(\)](#), [SimSSMLinGrowth\(\)](#), [SimSSMOUIVary\(\)](#), [SimSSMOU\(\)](#), [SimSSMVARFixed\(\)](#), [SimSSMVARIVary\(\)](#), [SimSSMVAR\(\)](#), [SimSSM\(\)](#)

**Examples**

```
# prepare parameters
set.seed(42)
p <- k <- 2
iden <- diag(p)
n <- 5
mu0 <- c(-3.0, 1.5)
sigma0 <- iden
mu <- c(5.76, 5.18)
```

```

phi <- matrix(data = c(0.10, -0.05, -0.05, 0.10), nrow = p)
sigma <- matrix(
  data = c(2.79, 0.06, 0.06, 3.27),
  nrow = p
)
nu <- rep(x = 0, times = k)
lambda <- diag(k)
theta <- diag(x = 0.50, nrow = k)
delta_t <- 0.10
time <- 50
burn_in <- 0
gamma_y <- gamma_eta <- 0.10 * diag(k)
x <- lapply(
  X = seq_len(n),
  FUN = function(i) {
    return(
      matrix(
        data = rnorm(n = k * (time + burn_in)),
        ncol = k
      )
    )
  }
)

# Type 0
SimSSMOUFixed(
  n = n,
  mu0 = mu0,
  sigma0 = sigma0,
  mu = mu,
  phi = phi,
  sigma = sigma,
  nu = nu,
  lambda = lambda,
  theta = theta,
  type = 0,
  delta_t = delta_t,
  time = time,
  burn_in = burn_in
)

# Type 1
SimSSMOUFixed(
  n = n,
  mu0 = mu0,
  sigma0 = sigma0,
  mu = mu,
  phi = phi,
  sigma = sigma,
  nu = nu,
  lambda = lambda,
  theta = theta,
  gamma_eta = gamma_eta,

```

```

    x = x,
    type = 1,
    delta_t = delta_t,
    time = time,
    burn_in = burn_in
)

# Type 2
SimSSMOUFixed(
  n = n,
  mu0 = mu0,
  sigma0 = sigma0,
  mu = mu,
  phi = phi,
  sigma = sigma,
  nu = nu,
  lambda = lambda,
  theta = theta,
  gamma_y = gamma_y,
  gamma_eta = gamma_eta,
  x = x,
  type = 2,
  delta_t = delta_t,
  time = time,
  burn_in = burn_in
)

```

---

SimSSMOUIVary

*Simulate Data from an Ornstein–Uhlenbeck Model using a State Space Model Parameterization for  $n > 1$  Individuals (Individual-Varying Parameters)*

---

## Description

This function simulates data from an Ornstein–Uhlenbeck model using a state space model parameterization for  $n > 1$  individuals. In this model, the parameters can vary across individuals.

## Usage

```

SimSSMOUIVary(
  n,
  mu0,
  sigma0,
  mu,
  phi,
  sigma,
  nu,
  lambda,

```

```

    theta,
    gamma_y = NULL,
    gamma_eta = NULL,
    x = NULL,
    type = 0,
    delta_t,
    time,
    burn_in = 0
)

```

### Arguments

n	Positive integer. Number of individuals.
mu0	Numeric vector. Mean of initial latent variable values ( $\mu_{\eta 0}$ ).
sigma0	Numeric matrix. The covariance matrix of initial latent variable values ( $\Sigma_{\eta 0}$ ).
mu	List of numeric vectors. Each element of the list is the long-term mean or equilibrium level ( $\mu$ ).
phi	List of numeric matrices. Each element of the list is the rate of mean reversion, determining how quickly the variable returns to its mean ( $\Phi$ ).
sigma	List of numeric matrices. Each element of the list is the matrix of volatility or randomness in the process ( $\Sigma$ ).
nu	Numeric vector. Vector of intercepts for the measurement model ( $\nu$ ).
lambda	Numeric matrix. Factor loading matrix linking the latent variables to the observed variables ( $\Lambda$ ).
theta	Numeric matrix. The measurement error covariance matrix ( $\Theta$ ).
gamma_y	Numeric matrix. Matrix relating the values of the covariate matrix at time t to the observed variables at time t ( $\Gamma_y$ ).
gamma_eta	Numeric matrix. Matrix relating the values of the covariate matrix at time t to the latent variables at time t ( $\Gamma_{\eta}$ ).
x	Numeric matrix. The matrix of observed covariates in type = 1 or type = 2. The number of rows should be equal to time + burn_in.
type	Integer. State space model type.
delta_t	Numeric. Time interval ( $\delta_t$ ).
time	Positive integer. Number of time points to simulate.
burn_in	Positive integer. Number of burn-in points to exclude before returning the results.

### Details

Parameters can vary across individuals by providing a list of parameter values. If the length of any of the parameters (mu0, sigma0, mu, phi, sigma, nu, lambda, theta, gamma\_y, or gamma\_eta) is less than n, the function will cycle through the available values.

**Value**

Returns a list with the following elements:

- call: Function call.
- args: Function arguments.
- data: Generated data which is a list of length n.
- fun: Function used.

Each element of data is a list with the following elements:

- id: A vector of ID numbers of length t.
- time: A vector of discrete time points from 0 to t - 1.
- y: A t by k matrix of values for the manifest variables.
- eta: A t by p matrix of values for the latent variables.
- x: A t by j matrix of values for the covariates.

**Author(s)**

Ivan Jacob Agaloos Pesigan

**References**

Chow, S.-M., Losardo, D., Park, J., & Molenaar, P. C. M. (2023). Continuous-time dynamic models: Connections to structural equation models and other discrete-time models. In R. H. Hoyle (Ed.), *Handbook of structural equation modeling* (2nd ed.). The Guilford Press.

Uhlenbeck, G. E., & Ornstein, L. S. (1930). On the theory of the brownian motion. *Physical Review*, 36(5), 823–841. doi:10.1103/physrev.36.823

**See Also**

Other Simulation of State Space Models Data Functions: [OU2SSM\(\)](#), [SimSSMFixed\(\)](#), [SimSSMIVary\(\)](#), [SimSSMLinGrowthIVary\(\)](#), [SimSSMLinGrowth\(\)](#), [SimSSMOUFixed\(\)](#), [SimSSMOU\(\)](#), [SimSSMVARFixed\(\)](#), [SimSSMVARIVary\(\)](#), [SimSSMVAR\(\)](#), [SimSSM\(\)](#)

**Examples**

```
# prepare parameters
# In this example, phi varies across individuals
set.seed(42)
p <- k <- 2
iden <- diag(p)
n <- 5
mu0 <- list(c(-3.0, 1.5))
sigma0 <- list(iden)
mu <- list(c(5.76, 5.18))
phi <- list(
  as.matrix(Matrix::expm(diag(x = -0.1, nrow = k))),
  as.matrix(Matrix::expm(diag(x = -0.2, nrow = k))),
```

```

    as.matrix(Matrix::expm(diag(x = -0.3, nrow = k))),
    as.matrix(Matrix::expm(diag(x = -0.4, nrow = k))),
    as.matrix(Matrix::expm(diag(x = -0.5, nrow = k)))
  )
  sigma <- list(
    matrix(data = c(2.79, 0.06, 0.06, 3.27), nrow = p)
  )
  nu <- list(rep(x = 0, times = k))
  lambda <- list(diag(k))
  theta <- list(diag(x = 0.50, nrow = k))
  delta_t <- 0.10
  time <- 50
  burn_in <- 0
  gamma_y <- gamma_eta <- list(0.10 * diag(k))
  x <- lapply(
    X = seq_len(n),
    FUN = function(i) {
      return(
        matrix(
          data = rnorm(n = k * (time + burn_in)),
          ncol = k
        )
      )
    }
  )
)
```

```

# Type 0
SimSSMOUIVary(
  n = n,
  mu0 = mu0,
  sigma0 = sigma0,
  mu = mu,
  phi = phi,
  sigma = sigma,
  nu = nu,
  lambda = lambda,
  theta = theta,
  type = 0,
  delta_t = delta_t,
  time = time,
  burn_in = burn_in
)
```

```

# Type 1
SimSSMOUIVary(
  n = n,
  mu0 = mu0,
  sigma0 = sigma0,
  mu = mu,
  phi = phi,
  sigma = sigma,
  nu = nu,
  lambda = lambda,

```



```

        theta = theta,
        gamma_eta = gamma_eta,
        x = x,
        type = 1,
        delta_t = delta_t,
        time = time,
        burn_in = burn_in
    )

# Type 2
SimSSMOUIVary(
    n = n,
    mu0 = mu0,
    sigma0 = sigma0,
    mu = mu,
    phi = phi,
    sigma = sigma,
    nu = nu,
    lambda = lambda,
    theta = theta,
    gamma_y = gamma_y,
    gamma_eta = gamma_eta,
    x = x,
    type = 2,
    delta_t = delta_t,
    time = time,
    burn_in = burn_in
)

```

---

SimSSMVAR

*Simulate Data from the Vector Autoregressive Model using a State Space Model Parameterization ( $n = 1$ )*

---

## Description

This function simulates data from the vector autoregressive model using a state space model parameterization. See details for more information.

## Usage

```

SimSSMVAR(
    mu0,
    sigma0,
    alpha,
    beta,
    psi,
    gamma_eta = NULL,
    x = NULL,

```

```

    time = 0,
    burn_in = 0
)

```

### Arguments

mu0	Numeric vector. Mean of initial latent variable values ( $\mu_{\eta 0}$ ).
sigma0	Numeric matrix. The covariance matrix of initial latent variable values ( $\Sigma_{\eta 0}$ ).
alpha	Numeric vector. Vector of intercepts for the dynamic model ( $\alpha$ ).
beta	Numeric matrix. Transition matrix relating the values of the latent variables at time $t - 1$ to those at time $t$ ( $\beta$ ).
psi	Numeric matrix. The process noise covariance matrix ( $\Psi$ ).
gamma_eta	Numeric matrix. Matrix relating the values of the covariate matrix at time $t$ to the latent variables at time $t$ ( $\Gamma_{\eta}$ ).
x	Numeric matrix. The matrix of observed covariates in <code>type = 1</code> or <code>type = 2</code> . The number of rows should be equal to <code>time + burn_in</code> .
time	Positive integer. Number of time points to simulate.
burn_in	Positive integer. Number of burn-in points to exclude before returning the results.

### Details

The measurement model is given by

$$\mathbf{y}_t = \boldsymbol{\eta}_t.$$

The dynamic structure is given by

$$\boldsymbol{\eta}_t = \boldsymbol{\alpha} + \boldsymbol{\beta}\boldsymbol{\eta}_{t-1} + \boldsymbol{\zeta}_t \quad \text{with} \quad \boldsymbol{\zeta}_t \sim \mathcal{N}(\mathbf{0}, \boldsymbol{\Psi})$$

where  $\boldsymbol{\eta}_t$ ,  $\boldsymbol{\eta}_{t-1}$ , and  $\boldsymbol{\zeta}_t$  are random variables, and  $\boldsymbol{\alpha}$ ,  $\boldsymbol{\beta}$ , and  $\boldsymbol{\Psi}$  are model parameters.  $\boldsymbol{\eta}_t$  is a vector of latent variables at time  $t$ ,  $\boldsymbol{\eta}_{t-1}$  is a vector of latent variables at time  $t - 1$ , and  $\boldsymbol{\zeta}_t$  is a vector of dynamic noise at time  $t$ .  $\boldsymbol{\alpha}$  is a vector of intercepts,  $\boldsymbol{\beta}$  is a matrix of autoregression and cross regression coefficients, and  $\boldsymbol{\Psi}$  is the covariance matrix of  $\boldsymbol{\zeta}_t$ .

Note that when `gamma_eta` and `x` are not NULL, the dynamic structure is given by

$$\boldsymbol{\eta}_t = \boldsymbol{\alpha} + \boldsymbol{\beta}\boldsymbol{\eta}_{t-1} + \boldsymbol{\Gamma}_{\eta}\mathbf{x}_t + \boldsymbol{\zeta}_t \quad \text{with} \quad \boldsymbol{\zeta}_t \sim \mathcal{N}(\mathbf{0}, \boldsymbol{\Psi})$$

where  $\mathbf{x}_t$  is a vector of covariates at time  $t$ , and  $\boldsymbol{\Gamma}_{\eta}$  is the coefficient matrix linking the covariates to the latent variables.

### Value

Returns a list with the following elements:

- `call`: Function call.
- `args`: Function arguments.
- `data`: Generated data which is a list of length `n`.

- fun: Function used.

data is a list with the following elements:

- id: A vector of ones.
- time: A vector of discrete time points from 0 to  $t - 1$ .
- y: A  $t$  by  $k$  matrix of values for the manifest variables.
- eta: A  $t$  by  $p$  matrix of values for the latent variables.
- x: A  $t$  by  $j$  matrix of values for the covariates.

## References

Chow, S.-M., Ho, M. R., Hamaker, E. L., & Dolan, C. V. (2010). Equivalence and differences between structural equation modeling and state-space modeling techniques. *Structural Equation Modeling: A Multidisciplinary Journal*, 17(2), 303–332. doi:10.1080/10705511003661553

## See Also

Other Simulation of State Space Models Data Functions: [OU2SSM\(\)](#), [SimSSMFixed\(\)](#), [SimSSMIVary\(\)](#), [SimSSMLinGrowthIVary\(\)](#), [SimSSMLinGrowth\(\)](#), [SimSSMOUFixed\(\)](#), [SimSSMOUIVary\(\)](#), [SimSSMOU\(\)](#), [SimSSMVARFixed\(\)](#), [SimSSMVARIVary\(\)](#), [SimSSM\(\)](#)

## Examples

```
# prepare parameters
set.seed(42)
k <- 3
iden <- diag(k)
null_vec <- rep(x = 0, times = k)
mu0 <- null_vec
sigma0 <- iden
alpha <- null_vec
beta <- diag(x = 0.5, nrow = k)
psi <- iden
time <- 50
burn_in <- 0
gamma_eta <- 0.10 * diag(k)
x <- matrix(
  data = rnorm(n = k * (time + burn_in)),
  ncol = k
)

# No covariates
SimSSMVAR(
  mu0 = mu0,
  sigma0 = sigma0,
  alpha = alpha,
  beta = beta,
  psi = psi,
  time = time,
  burn_in = burn_in
```

```

)

# With covariates
SimSSMVAR(
  mu0 = mu0,
  sigma0 = sigma0,
  alpha = alpha,
  beta = beta,
  psi = psi,
  gamma_eta = gamma_eta,
  x = x,
  time = time,
  burn_in = burn_in
)

```

---

SimSSMVARFixed

---

*Simulate Data from a Vector Autoregressive Model using a State Space Model Parameterization for  $n > 1$  Individuals (Fixed Parameters)*


---

### Description

This function simulates data from a vector autoregressive model using a state space model parameterization for  $n > 1$  individuals. In this model, the parameters are invariant across individuals.

### Usage

```

SimSSMVARFixed(
  n,
  mu0,
  sigma0,
  alpha,
  beta,
  psi,
  gamma_eta = NULL,
  x = NULL,
  time = 0,
  burn_in = 0
)

```

### Arguments

n	Positive integer. Number of individuals.
mu0	Numeric vector. Mean of initial latent variable values ( $\mu_{\eta 0}$ ).
sigma0	Numeric matrix. The covariance matrix of initial latent variable values ( $\Sigma_{\eta 0}$ ).
alpha	Numeric vector. Vector of intercepts for the dynamic model ( $\alpha$ ).
beta	Numeric matrix. Transition matrix relating the values of the latent variables at time $t - 1$ to those at time $t$ ( $\beta$ ).

psi	Numeric matrix. The process noise covariance matrix ( $\Psi$ ).
gamma_eta	Numeric matrix. Matrix relating the values of the covariate matrix at time $t$ to the latent variables at time $t$ ( $\Gamma_{\eta}$ ).
x	A list of length $n$ of numeric matrices. Each element of the list is a matrix of observed covariates in $\text{type} = 1$ or $\text{type} = 2$ . The number of rows in each matrix should be equal to $\text{time} + \text{burn\_in}$ .
time	Positive integer. Number of time points to simulate.
burn_in	Positive integer. Number of burn-in points to exclude before returning the results.

### Value

Returns a list with the following elements:

- call: Function call.
- args: Function arguments.
- data: Generated data which is a list of length  $n$ .
- fun: Function used.

Each element of data is a list with the following elements:

- id: A vector of ID numbers of length  $t$ .
- time: A vector of discrete time points from 0 to  $t - 1$ .
- y: A  $t$  by  $k$  matrix of values for the manifest variables.
- eta: A  $t$  by  $p$  matrix of values for the latent variables.
- x: A  $t$  by  $j$  matrix of values for the covariates.

### Author(s)

Ivan Jacob Agaloos Pesigan

### References

Chow, S.-M., Ho, M. R., Hamaker, E. L., & Dolan, C. V. (2010). Equivalence and differences between structural equation modeling and state-space modeling techniques. *Structural Equation Modeling: A Multidisciplinary Journal*, 17(2), 303–332. doi:10.1080/10705511003661553

### See Also

Other Simulation of State Space Models Data Functions: [OU2SSM\(\)](#), [SimSSMFixed\(\)](#), [SimSSMIVary\(\)](#), [SimSSMLinGrowthIVary\(\)](#), [SimSSMLinGrowth\(\)](#), [SimSSMOUFixed\(\)](#), [SimSSMOUIVary\(\)](#), [SimSSMOU\(\)](#), [SimSSMVARIVary\(\)](#), [SimSSMVAR\(\)](#), [SimSSM\(\)](#)

**Examples**

```

# prepare parameters
set.seed(42)
k <- 3
iden <- diag(k)
null_vec <- rep(x = 0, times = k)
n <- 5
mu0 <- null_vec
sigma0 <- iden
alpha <- null_vec
beta <- diag(x = 0.5, nrow = k)
psi <- iden
time <- 50
burn_in <- 0
gamma_eta <- 0.10 * diag(k)
x <- lapply(
  X = seq_len(n),
  FUN = function(i) {
    return(
      matrix(
        data = rnorm(n = k * (time + burn_in)),
        ncol = k
      )
    )
  }
)

# No covariates
SimSSMVARFixed(
  n = n,
  mu0 = mu0,
  sigma0 = sigma0,
  alpha = alpha,
  beta = beta,
  psi = psi,
  time = time,
  burn_in = burn_in
)

# With covariates
SimSSMVARFixed(
  n = n,
  mu0 = mu0,
  sigma0 = sigma0,
  alpha = alpha,
  beta = beta,
  psi = psi,
  gamma_eta = gamma_eta,
  x = x,
  time = time,
  burn_in = burn_in
)

```

---

SimSSMVARIVary	<i>Simulate Data from a Vector Autoregressive Model using a State Space Model Parameterization for <math>n &gt; 1</math> Individuals (Individual-Varying Parameters)</i>
----------------	--

---

### Description

This function simulates data from a vector autoregressive model using a state space model parameterization for  $n > 1$  individuals. In this model, the parameters can vary across individuals.

### Usage

```
SimSSMVARIVary(
  n,
  mu0,
  sigma0,
  alpha,
  beta,
  psi,
  gamma_eta = NULL,
  x = NULL,
  time = 0,
  burn_in = 0
)
```

### Arguments

n	Positive integer. Number of individuals.
mu0	List of numeric vectors. Each element of the list is the mean of initial latent variable values ( $\mu_{\eta 0}$ ).
sigma0	List of numeric matrices. Each element of the list is the covariance matrix of initial latent variable values ( $\Sigma_{\eta 0}$ ).
alpha	List of numeric vectors. Each element of the list is the vector of intercepts for the dynamic model ( $\alpha$ ).
beta	List of numeric matrices. Each element of the list is the transition matrix relating the values of the latent variables at time $t - 1$ to those at time $t$ ( $\beta$ ).
psi	List of numeric matrices. Each element of the list is the process noise covariance matrix ( $\Psi$ ).
gamma_eta	Numeric matrix. Matrix relating the values of the covariate matrix at time $t$ to the latent variables at time $t$ ( $\Gamma_{\eta}$ ).
x	A list of length $n$ of numeric matrices. Each element of the list is a matrix of observed covariates in type = 1 or type = 2. The number of rows in each matrix should be equal to $\text{time} + \text{burn\_in}$ .

time	Positive integer. Number of time points to simulate.
burn_in	Positive integer. Number of burn-in points to exclude before returning the results.

### Details

Parameters can vary across individuals by providing a list of parameter values. If the length of any of the parameters ( $\mu_0$ ,  $\sigma_0$ ,  $\alpha$ ,  $\beta$ ,  $\psi$ , or  $\gamma_{\eta}$ ) is less than  $n$ , the function will cycle through the available values.

### Value

Returns a list with the following elements:

- call: Function call.
- args: Function arguments.
- data: Generated data which is a list of length  $n$ .
- fun: Function used.

Each element of data is a list with the following elements:

- id: A vector of ID numbers of length  $t$ .
- time: A vector of discrete time points from 0 to  $t - 1$ .
- y: A  $t$  by  $k$  matrix of values for the manifest variables.
- eta: A  $t$  by  $p$  matrix of values for the latent variables.
- x: A  $t$  by  $j$  matrix of values for the covariates.

### Author(s)

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### References

Chow, S.-M., Ho, M. R., Hamaker, E. L., & Dolan, C. V. (2010). Equivalence and differences between structural equation modeling and state-space modeling techniques. *Structural Equation Modeling: A Multidisciplinary Journal*, 17(2), 303–332. doi:10.1080/10705511003661553

### See Also

Other Simulation of State Space Models Data Functions: [OU2SSM\(\)](#), [SimSSMFixed\(\)](#), [SimSSMIVary\(\)](#), [SimSSMLinGrowthIVary\(\)](#), [SimSSMLinGrowth\(\)](#), [SimSSMOUFixed\(\)](#), [SimSSMOUIVary\(\)](#), [SimSSMOU\(\)](#), [SimSSMVARFixed\(\)](#), [SimSSMVAR\(\)](#), [SimSSM\(\)](#)



**Examples**

```

# prepare parameters
# In this example, beta varies across individuals
set.seed(42)
k <- 3
iden <- diag(k)
null_vec <- rep(x = 0, times = k)
n <- 5
mu0 <- list(null_vec)
sigma0 <- list(iden)
alpha <- list(null_vec)
beta <- list(
  diag(x = 0.1, nrow = k),
  diag(x = 0.2, nrow = k),
  diag(x = 0.3, nrow = k),
  diag(x = 0.4, nrow = k),
  diag(x = 0.5, nrow = k)
)
psi <- list(iden)
time <- 50
burn_in <- 0
gamma_eta <- list(0.10 * diag(k))
x <- lapply(
  X = seq_len(n),
  FUN = function(i) {
    return(
      matrix(
        data = rnorm(n = k * (time + burn_in)),
        ncol = k
      )
    )
  }
)

# No covariates
SimSSMVARIVary(
  n = n,
  mu0 = mu0,
  sigma0 = sigma0,
  alpha = alpha,
  beta = beta,
  psi = psi,
  time = time,
  burn_in = burn_in
)

# With covariates
SimSSMVARIVary(
  n = n,
  mu0 = mu0,
  sigma0 = sigma0,
  alpha = alpha,

```

```
    beta = beta,  
    psi = psi,  
    gamma_eta = gamma_eta,  
    x = x,  
    time = time,  
    burn_in = burn_in  
)
```

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