

# Package ‘EMLI’

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**Type** Package

**Title** Computationally Efficient Maximum Likelihood Identification of  
Linear Dynamical Systems

**Version** 0.2.0

**Description** Provides implementations of computationally efficient maximum likelihood parameter estimation algorithms for models that represent linear dynamical systems. Currently, one such algorithm is implemented for the one-dimensional cumulative structural equation model with shock-error output measurement equation and assumptions of normality and independence. The corresponding scientific paper is yet to be published, therefore the relevant reference will be provided later.

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calculate\_likelihood    *calculate\_likelihood*

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### Description

Calculates the likelihood function value for given data and statistical measure values of the output-differenced version of the one-dimensional cumulative structural equation model with shock-error output measurement equation and assumptions of normality and independence. Suitable when there are no contradictions in statistical measure values.

### Usage

```
calculate_likelihood(dat, params)
```

### Arguments

dat	An $(n + 1) \times (m + 1)$ data frame of finite numeric elements (possibly except for row 1 columns 1 to $m$ ) containing observed input (columns 1 to $m$ ) and output (column $m + 1$ ) data of the original model.
params	A list consisting of 3 elements: 1) Sigma $((m + 1) \times (m + 1)$ matrix of finite numeric elements); 2) $\sigma_y^2$ (vector of length 1, finite numeric element); 3) $\mu$ $((m + 1) \times 1$ matrix of finite numeric elements).

### Value

Calculated likelihood function value (vector of length 1, numeric element).

### Examples

```
set.seed(1)

m <- 4
k <- 2

L <- matrix(runif((m + 1) * k, min = -10, max = 10), nrow = m + 1)
sigma <- matrix(runif(m + 2, min = 0, max = 10), nrow = m + 2)
mu <- matrix(runif(m + 1, min = -10, max = 10), nrow = m + 1)

data <- generate_data(100, L, sigma, mu)
estimated_parameters <- estimate_parameters(data, 0.00001)

calculate_likelihood(data, estimated_parameters)
```

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estimate\_parameters    *estimate\_parameters*

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### Description

Calculates maximum likelihood estimates of the statistical measures of the output-differenced version of the one-dimensional cumulative structural equation model with shock-error output measurement equation and assumptions of normality and independence.

### Usage

```
estimate_parameters(dat, tol)
```

### Arguments

dat	An $(n + 1) \times (m + 1)$ data frame of finite numeric elements (possibly except for row 1 columns 1 to $m$ ) containing observed input (columns 1 to $m$ ) and output (column $m + 1$ ) data of the original model.
tol	A tolerance parameter of the golden section search algorithm used for minimizing the one-dimensional likelihood function (vector of length 1, finite positive numeric element).

### Value

A list consisting of 3 elements: 1) estimate of the covariance at lag 0 of the data that result from the output-differenced model (Sigma;  $(m + 1) \times (m + 1)$  matrix of numeric elements); 2) estimate of the only non-zero element of the negative covariance at lag 1 of the data that result from the output-differenced model (sigma\_y^2; vector of length 1, numeric element); 3) estimate of the mean of the data that result from the output-differenced model (mu;  $(m + 1) \times 1$  matrix of numeric elements).

### Examples

```
set.seed(1)

m <- 4
k <- 2

L <- matrix(runif((m + 1) * k, min = -10, max = 10), nrow = m + 1)
sigma <- matrix(runif(m + 2, min = 0, max = 10), nrow = m + 2)
mu <- matrix(runif(m + 1, min = -10, max = 10), nrow = m + 1)

data <- generate_data(100, L, sigma, mu)

estimate_parameters(data, 0.00001)
```

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evaluate\_estimates      *evaluate\_estimates*

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### Description

Calculates a discrepancy-function-based metric of accuracy of the statistical measure estimates for the output-differenced version of the one-dimensional cumulative structural equation model with shock-error output measurement equation and assumptions of normality and independence. Suitable when there are no contradictions in the factials/estimates.

### Usage

```
evaluate_estimates(f, e, n)
```

### Arguments

f	A list consisting of 3 elements: 1) the factual Sigma $((m + 1) \times (m + 1))$ matrix of finite numeric elements); 2) the factual $\sigma_y^2$ (vector of length 1, finite numeric element); 3) the factual mu $((m + 1) \times 1)$ matrix of finite numeric elements).
e	Analogous to parameter f but with estimates instead of factials.
n	The number of time moments used for obtaining parameter e (vector of length 1, finite positive integer).

### Value

Calculated accuracy metric value (vector of length 1, numeric element). The lower the value, the better the accuracy, with 0 indicating perfect accuracy.

### Examples

```
set.seed(1)

m <- 4
k <- 2

L <- matrix(runif((m + 1) * k, min = -10, max = 10), nrow = m + 1)
sigma <- matrix(runif(m + 2, min = 0, max = 10), nrow = m + 2)
mu <- matrix(runif(m + 1, min = -10, max = 10), nrow = m + 1)

n <- 100
data <- generate_data(n, L, sigma, mu)

Sigma <- L %*% t(L) + diag(sigma[1:(m + 1), ] ^ 2)
sigma_y_squared <- sigma[m + 2, ] ^ 2
Sigma[m + 1, m + 1] <- Sigma[m + 1, m + 1] + 2 * sigma_y_squared

factual_parameters <- list(Sigma, sigma_y_squared, mu)
```

```

estimated_parameters <- estimate_parameters(data, 0.00001)

evaluate_estimates(factual_parameters, estimated_parameters, n)

```

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```

generate_data      generate_data

```

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### Description

Generates data according to the one-dimensional cumulative structural equation model with shock-error output measurement equation and assumptions of normality and independence with given model parameter values.

### Usage

```
generate_data(n, L, sigma, mu)
```

### Arguments

n	The number of time moments to generate the data for (vector of length 1, finite positive integer).
L	Factor loadings $((m + 1) \times k$ matrix of finite numeric elements: the first $m$ rows correspond to the input measurement equation; the last row corresponds to the transition equation).
sigma	Standard deviations of the error/noise terms $((m + 2) \times 1$ matrix of finite non-negative numeric elements: the first $m$ rows correspond to the input measurement equation; the row before the last one corresponds to the transition equation; the last row corresponds to the output measurement equation).
mu	Intercept terms $((m + 1) \times 1$ matrix of finite numeric elements; the first $m$ rows correspond to the input measurement equation; the last row corresponds to the transition equation).

### Value

An  $(n + 1) \times (m + 1)$  data frame of numeric elements (except for row 1 columns 1 to  $m$  that contain NA's) containing observed input (columns 1 to  $m$ ) and output (column  $m + 1$ ) data.

### Examples

```

set.seed(1)

m <- 4
k <- 2

L <- matrix(runif((m + 1) * k, min = -10, max = 10), nrow = m + 1)
sigma <- matrix(runif(m + 2, min = 0, max = 10), nrow = m + 2)
mu <- matrix(runif(m + 1, min = -10, max = 10), nrow = m + 1)

```

```
generate_data(10, L, sigma, mu)
```

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