

Package ‘SAutomata’

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Type Package

Title Inference and Learning in Stochastic Automata

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Maintainer Muhammad Kashif Hanif <mkashifhanif@gcuf.edu.pk>

Description Machine learning provides algorithms that can learn from data and make inferences or predictions. Stochastic automata is a class of input/output devices which can model components. This work provides implementation an inference algorithm for stochastic automata which is similar to the Viterbi algorithm. Moreover, we specify a learning algorithm using the expectation-maximization technique and provide a more efficient implementation of the Baum-Welch algorithm for stochastic automata. This work is based on Inference and learning in stochastic automata was by Karl-Heinz Zimmermann(2017) <[doi:10.12732/ijpam.v11i3.15](https://doi.org/10.12732/ijpam.v11i3.15)>.

License GPL (>= 3)

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Author Muhammad Kashif Hanif [cre, aut],
Muhammad Umer Sarwar [aut],
Rehman Ahmad [aut],
Zeeshan Ahmad [aut],
Karl-Heinz Zimmermann [aut]

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BaumWelch	<i>Inferring the Forward and Backward Probabilities of a Stochastic Automata Model via the Baum-Welch algorithm</i>
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Description

For an initial Stochastic Automata Model (SA) and a given sequence of observations, the Baum-Welch algorithm infers optimal forward and backward probabilities to the SA. Since the Baum-Welch algorithm is a variant of the Expectation-Maximisation algorithm, the algorithm converges to a local solution which might not be the global optimum.

Usage

```
BaumWelch(initsa, x, y, m, error, theta = NULL)
```

Arguments

initsa	A Stochastic Automata Model.
x	A sequence of inputs.
y	A sequence of outputs.
m	Maximum length of sequence to create sample set for learning.
error	Maximum error rate.
theta	Optional Conditional Probabilities.

Value

Returns the conditional probabilities by learning the sample set.

Examples

```
states<-c('s1','s2')
inputSymbols<-c('a','b')
outputSymbols<-c(0,1)
transProb<-matrix(c(0.70,0.50, 0.30,0.50), nrow = 2, ncol = 2,byrow = TRUE)
emissionProb<-matrix(c(0.50,0.30, 0.40,0.60,.50,.70,.60,.40), nrow = 2, ncol = 4, byrow = TRUE)
initsa<-initSA(states,inputSymbols,outputSymbols,emissionProb,transProb)
x<-c('b','a')
y<-c(0,1)
m<-1
error<-10
BaumWelch(initsa, x, y, m, error)
```

`initSA`*Initialisation of SA's*

Description

This function initialises a general discrete time and discrete space Stochastic Automata(SA). A SA consists of an alphabet of states, input and output symbols. The SA is designed to make inference on the states through the observation of input symbols on output symbols. The stochastics of the SA is fully described by the set of states, input and output symbols and the conditional probabilities (i.e. state transition probability and output symbols emission probability by inputs symbols on state set).

Usage

```
initSA(states,inputSymbols,outputSymbols,emissionProb,transitionProb)
```

Arguments

<code>states</code>	Vector with names of states.
<code>inputSymbols</code>	Vector with names of input Symbols.
<code>outputSymbols</code>	Vector with names of output Symbols.
<code>emissionProb</code>	Stochastic matrix containing emission probabilities of output symbols between states and input symbols.
<code>transitionProb</code>	Stochastic matrix containing probabilities between states.

Details

The column sum of `transitionProb` and `emissionProb` must be equal to 1. Otherwise this function generates an error message.

Value

This function `initSA` returns an SA that consists of a list of 5 elements:

<code>States</code>	Vector with names of states.
<code>inputSymbols</code>	Vector with names of input Symbols.
<code>outputSymbols</code>	Vector with names of output Symbols.
<code>outputSymbols</code>	Vector with names of output Symbols.
<code>emissionProb</code>	Annotated matrix containing emission probabilities of output symbols between states and input symbols.
<code>transitionProb</code>	Annotated matrix containing probabilities between states.

Author(s)

Rehman Ahmad <rehman.ahmad777@gmail.com>

Examples

```

states<-c('s1','s2')
inputSymbols<-c('a','b')
outputSymbols<-c(0,1)
transProb<-matrix(c(0.70,0.50, 0.30,0.50), nrow = 2, ncol = 2,byrow = TRUE)
emissionProb<-matrix(c(0.50,0.30, 0.40,0.60,.50,.70,.60,.40), nrow = 2, ncol = 4, byrow = TRUE)
initsa<-initSA(states,inputSymbols,outputSymbols,emissionProb,transProb)

```

Sbackward

Computes The Backward Probabilities

Description

The Sbackward function computes the backward probabilities. The backward probabilities for state 'S' up to output observations at time k is defined as the probability of observing the sequence of observations 'Y'(y₁, ... ,y_k) and that state at time 'k' is 'S'. that is:

$$f[k,X] := \text{Prob}(Y_{k+1} = y_{k+1}, \dots, Y_k = y_k, S_k = S).$$

Where Y₁, ... ,Y_n = y₁, ... , y_n is sequence of observed emissions and S_k is a random variable that represents the state at time k.

Usage

```
Sbackward(initsa, x, y, theta=NULL)
```

Arguments

initsa	A Stochastic Model.
x	A vector of input sequence.
y	A vector of Output sequence.
theta	Optional Conditional Probabilities.

Value

Return Value:

backward A matrix containing the backward probabilities. The probabilities are given on a logarithmic scale (natural logarithm). This first dimension refer to the time and the second dimension to states.

Author(s)

Rehman Ahmad <rehman.ahmad777@gmail.com>

Examples

```
states<-c('s1','s2')
inputSymbols<-c('a','b')
outputSymbols<-c(0,1)
transProb<-matrix(c(0.70,0.50, 0.30,0.50), nrow = 2, ncol = 2,byrow = TRUE)
emissionProb<-matrix(c(0.50,0.30, 0.40,0.60,.50,.70,.60,.40), nrow = 2, ncol = 4, byrow = TRUE)
initsa<-initSA(states,inputSymbols,outputSymbols,emissionProb,transProb)
x<-c('b','a')
y<-c(0,1)
sb<-Sbackward(initsa, x, y)
```

scores

Calculation of Probabilities (Not For End User)

Description

This function is not for end user.

Usage

```
scores(initsa=NULL,theta=NULL)
```

Arguments

initsa	Model SA.
theta	Optional(Conditional Probabilities).

Examples

```
## Not run:
scores(initsa)

## End(Not run)
```

Sforward

Computes The Forward Probabilities

Description

The Sforward function computes the forward probabilities. The forward probabilities for state 'S' up to output observations at time k is defined as the probability of observing the sequence of observations 'Y'(y_1, ... ,y_k) and that state at time 'k' is 'S'. that is:

$$f[k,X] := \text{Prob}(Y_1 = y_1, \dots, Y_k = y_k, S_k = S).$$

Where $Y_1, \dots, Y_n = y_1, \dots, y_n$ is sequence of observed emissions and S_k is a random variable that represents the state at time k.

Usage

```
Sforward(initsa, x, y, theta=NULL)
```

Arguments

initsa	A Stochastic Model.
x	A vector of input sequence.
y	A vector of Output sequence.
theta	Optional Conditional Probabilities.

Value

Return Value:

forward A matrix containing the forward probabilities. The probabilities are given on a logarithmic scale (natural logarithm). This first dimension refer to the time and the second dimension to states.

Author(s)

Rehman Ahmad <rehman.ahmad777@gmail.com>

Examples

```
states<-c('s1','s2')
inputSymbols<-c('a','b')
outputSymbols<-c(0,1)
transProb<-matrix(c(0.70,0.50, 0.30,0.50), nrow = 2, ncol = 2,byrow = TRUE)
emissionProb<-matrix(c(0.50,0.30, 0.40,0.60,.50,.70,.60,.40), nrow = 2, ncol = 4, byrow = TRUE)
initsa<-initSA(states,inputSymbols,outputSymbols,emissionProb,transProb)
x<-c('b','a')
y<-c(0,1)
sf<-Sforward(initsa, x, y)
```

TOC.sampleData *Learning (Not For End User)*

Description

This function is not for end user.

Usage

```
TOC.sampleData(initsa=NULL,n)
```

Arguments

initsa	SA Model.
n	Length of input sample set sequence.

Examples

```
## Not run:
states<-c('s1','s2')
inputSymbols<-c('a','b')
outputSymbols<-c(0,1)
transProb<-matrix(c(0.70,0.50, 0.30,0.50), nrow = 2, ncol = 2,byrow = TRUE)
emissionProb<-matrix(c(0.50,0.30, 0.40,0.60,.50,.70,.60,.40), nrow = 2, ncol = 4, byrow = TRUE)
initsa<-initsa(states,inputSymbols,outputSymbols,emissionProb,transProb)
n<-3
TOC.sampleData(initsa, n)
```



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

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