

# Package ‘Icens’

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**Title** NPMLE for Censored and Truncated Data

**Description** Many functions for computing the NPMLE for censored and truncated data.

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Bisect

*An implementation of the bisection algorithm for root finding.*

---

## Description

Most of the optimizations in *Icens* have a one dimensional root-finding component. Since the quantities involved are generally restricted to a subset of  $[0,1]$  we use bisection to find the roots.

## Usage

```
Bisect(tA, pvec, ndir, Meps, tolbis=1e-07)
```

## Arguments

tA	The transpose of the clique matrix.
pvec	The current estimate of the probability vector.
ndir	The direction to explore.
Meps	Machine epsilon, elements of pvec that are less than this are assumed to be zero.
tolbis	The tolerance used to determine if the algorithm has converged.

## Details

We search from pvec in the direction ndir to obtain the new value of pvec that maximizes the likelihood.

## Value

The new estimate of pvec.

## Author(s)

Alain Vandal and Robert Gentleman.

**References**

Any book on optimization.

---

BVcliques	<i>Find the bivariate cliques from the marginal data.</i>
-----------	---

---

**Description**

The maximal cliques of the intersection graph are obtained by first finding the cliques for the marginal data and then combining them using the algorithm in Gentleman and Vandal (1999).

**Usage**

```
BVcliques(intvlx, intvly, Lxopen=TRUE, Rxopen=FALSE,
          Lyopen=TRUE, Ryopen=FALSE )
```

**Arguments**

intvlx	The cliques for one marginal component, alternatively the marginal intervals can be supplied.
intvly	The cliques for the other marginal component, alternatively the marginal intervals can be supplied.
Lxopen	Boolean indicating whether the left end point in the x coordinate is open.
Rxopen	Boolean indicating whether the right end point in the x coordinate is open.
Lyopen	Boolean indicating whether the left end point in the y coordinate is open.
Ryopen	Boolean indicating whether the right end point in the y coordinate is open.

**Value**

A list of the maximal cliques of the intersection graph of the data.

**Author(s)**

A. Vandal and R. Gentleman

**References**

*Graph-Theoretical Aspects of Bivariate Censored Data*, R. Gentleman and A. Vandal, 1999, submitted.

**See Also**

[BVclmat](#), [BVsupport](#)

**Examples**

```
data(cmv)
cmv.cl <- BVcliques(cmv[,1:2], cmv[,3:4], Lxopen=FALSE, Lyopen=FALSE )
```

---

**BVclmat***Compute the clique matrix from the clique list.*

---

**Description**

Given the clique list, obtained from [BVcliques](#), the clique matrix is obtained. This is the  $m$  (number of cliques) by  $n$  (number of observations) matrix.  $A[i,j]$  is one if individual  $j$  is in maximal clique  $i$ .

**Usage**

```
BVclmat(cliques)
```

**Arguments**

`cliques`      The clique list.

**Value**

The  $m$  by  $n$  clique matrix.

**Author(s)**

A. Vandal and R. Gentleman

**References**

*Graph-Theoretical Aspects of Bivariate Censored Data*, R. Gentleman and A. Vandal, 1999, submitted.

**See Also**

[BVcliques](#), [BVsupport](#)

**Examples**

```
data(cmv)
bcl <- BVcliques(cmv[,1:2], cmv[,3:4])
A <- BVclmat(bcl)
```

---

**BVsupport***Compute the support for the cliques of a bivariate intersection graph.*

---

**Description**

Given the regions where the events occurred and the cliques of the intersection graph the support of the cliques is computed. For each clique it is the intersection of the event time regions for all observations in that clique.

**Usage**

```
BVsupport(intvlx, intvly, cliques=BVcliques(intvlx, intvly))
```

**Arguments**

`intvlx`            The event time intervals for one dimension.  
`intvly`            The event time intervals for the other dimension.  
`cliques`           The list of maximal cliques of the intersection graph, optionally.

**Value**

An  $m$  by 4 matrix containing the corners of the intervals of support for the maximal cliques of the intersection graph corresponding to the first two arguments to the function.

**Author(s)**

A. Vandal and R. Gentleman

**References**

*Graph-Theoretical Aspects of Bivariate Censored Data*, R. Gentleman and A. Vandal, 1999, submitted.

**See Also**

[BVcliques](#), [BVclmat](#)

**Examples**

```
data(cmv)
cmv.cl <- BVcliques(cmv[,1:2], cmv[,3:4])
boxes <- BVsupport(cmv[,1:2], cmv[,3:4], cmv.cl)
```

---

cmv	<i>Data on times to shedding of cytomegalovirus and to colonization of mycobacterium avium complex.</i>
-----	---

---

### Description

The cmv data frame has 204 rows and 4 columns. The intervals should be treated as closed at both ends to replicate the analysis in Betensky and Finkelstein.

### Format

This data frame contains the following columns:

**cmvL** The left end of the CMV shedding interval.

**cmvR** The right end of the CMV shedding interval.

**macL** The left end of the MAC colonization interval.

**macR** The right end of the MAC colonization interval.

### Details

Betensky and Finkelstein, 1999 present data from the AIDS Clinical Trials Group protocol ACTG 181. This was a natural history substudy of a comparative trial. Patients were scheduled for clinic visits during follow-up and data was collected on the time until two events; shedding of cytomegalovirus (CMV) in the urine and blood and for colonization of mycobacterium avium complex (MAC) in the sputum or stool.

### Source

Betensky, R. A. and Finkelstein, D. M., 1999, *A nonparametric maximum likelihood estimator for bivariate interval censored data*, Statistics in Medicine,

### Examples

```
data(cmv)
```

---

cosmesis	<i>The time taken until cosmetic deterioration of breast cosmesis.</i>
----------	--

---

### Description

The cosmesis data frame has 95 rows and 3 columns.

**Format**

This data frame contains the following columns:

**L** The left end point of the cosmetic deterioration interval.

**R** The right end point of the cosmetic deterioration interval.

**Trt** The treatment indicator. It is zero for those that received radiotherapy.

**Source**

*A semiparametric model for regression analysis of interval-censored failure time data*, D. M. Finkelstein and R. A. Wolfe, 1985, Biometrics.

**Examples**

```
data(cosmesis)
```

---

EM	<i>A function to compute the NPMLE of <math>p</math> based on the incidence matrix <math>A</math>.</i>
----	--

---

**Description**

The incidence matrix,  $A$  is the  $m$  by  $n$  matrix that represents the data. There are  $m$  probabilities that must be estimated. The EM, or expectation maximization, method is applied to these data.

**Usage**

```
EM(A, pvec, maxiter=500, tol=1e-12)
```

**Arguments**

A	The incidence matrix.
pvec	The probability vector.
maxiter	The maximum number of iterations.
tol	The tolerance used to judge convergence.

**Details**

Lots.

**Value**

An object of class `icsurv` containing the following components:

pf	The NPMLE of the probability vector.
numiter	The number of iterations used.
converge	A boolean indicating whether the algorithm converged.
intmap	If present indicates the real representation of the support for the values in pf.

**Author(s)**

Alain Vandal and Robert Gentleman.

**References**

The EM algorithm applied to the maximal cliques of the intersection graph of the censored data. *The empirical distribution function with arbitrarily grouped, censored and truncated data*, B. W. Turnbull, 1976, JRSS;B.

**See Also**

[VEM](#), [ISDM](#), [EMICM](#), [PGM](#)

**Examples**

```
data(cosmesis)
csub1 <- subset(cosmesis, subset= Trt==0, select=c(L,R))
EM(csub1)
data(pruitt)
EM(pruitt)
```

---

EMICM

---

*Compute the NPMLE for censored data using the EMICM.*


---

**Description**

An implementation of the hybrid EM ICM (Iterative convex minorant) estimator of the distribution function proposed by Wellner and Zahn (1997).

**Usage**

```
EMICM(A, EMstep=TRUE, ICMstep=TRUE, keepiter=FALSE, tol=1e-07,
maxiter=1000)
```

**Arguments**

A	Either the m by n clique matrix or the n by 2 matrix containing the event time intervals.
EMstep	Boolean, indicating whether to take an EM step in the iteration.
ICMstep	Boolean, indicating whether to take an ICM step.
keepiter	Boolean determining whether to keep the iteration states.
tol	The maximal L1 distance between successive estimates before stopping iteration.
maxiter	The maximal number of iterations to perform before stopping.



**Details**

Lots, and they're complicated too!

**Value**

An object of class `icsurv` containing the following components:

<code>pf</code>	The estimated probabilities.
<code>sigma</code>	The NPMLE of the survival function on the maximal antichains.
<code>weights</code>	The diagonal of the likelihood function's second derivative.
<code>lastchange</code>	A vector of differences between the last two iterations.
<code>numiter</code>	The total number of iterations performed.
<code>iter</code>	Is only present if <code>keepiter</code> is true; states of <code>sigma</code> during the iteration.
<code>intmap</code>	The real representation associated with the probabilities reported in <code>pf</code> .

**Author(s)**

Alain Vandal and Robert Gentleman

**References**

*A hybrid algorithm for computation of the nonparametric maximum likelihood estimator from censored data*, J. A. Wellner and Y. Zhan, 1997, JASA.

**See Also**

[EM, VEM, PGM](#)

**Examples**

```
data(cosmesis)
csub1 <- subset(cosmesis, subset=Trt==0, select=c(L,R))
EMICM(csub1)
data(pruitt)
EMICM(pruitt)
```

---

hiv

*Intervals for infection time and disease onset for 257 hemophiliac patients.*

---

**Description**

The `hiv` data frame has 257 rows and 4 columns.

**Format**

This data frame contains the following columns:

**yL** The left end point of the infection time interval.

**yR** The right end point of the infection time interval.

**zL** The left end point of the disease onset interval.

**zR** The right end point of the disease onset interval.

**Age** Coded as 1 if the estimated age at infection was less than 20 and 2 if the estimated age at infection was greater than 20.

**Trt** Treatment, Light or Heavy

**Details**

The setting is as follows. Individuals were infected with the HIV virus at some unknown time they subsequently develop AIDS at a second unknown time. The data consist of two intervals,  $(y_L, y_R)$  and  $(z_L, z_R)$ , such that the infection time was in the first interval and the time of disease onset was in the second interval. A quantity of interest is the incubation time of the disease which is  $T = Z - Y$ . The authors argue persuasively that this should be considered as bivariate interval censored data. They note that simply forming the differences  $(z_L - y_R, z_R - y_L)$  and analysing the resultant data assumes an incorrect likelihood. DeGruttola and Lagakos transform the problem slightly to study the joint distribution of  $Y$  and  $T = Z - Y$ . This is equivalent to estimating the joint distribution of  $Z$  and  $Y$  then transforming. The data, as reported, have been discretized into six month intervals.

We use the data as reported in Table 1 of DeGruttola and Lagakos, 1989. The patients were 257 persons with Type A or B hemophilia treated at two hospitals in France. They were then examined intermittently (as they came in for treatment?) and their HIV and AIDS status was determined. Kim, De Gruttola and Lagakos report some covariate information and their paper is concerned with the modeling of that information. In this paper we concentrate only on the event times and ignore the covariate information; that topic being worthy of separate investigation.

**Source**

DeGruttola, V. and Lagakos, S.W., 1989, *Analysis of doubly-censored survival data, with application to AIDS*, Biometrics.

Kim, Mimi Y. and De Gruttola, Victor G. and Lagakos, Stephen W., 1993, *Analyzing Doubly Censored Data With Covariates, With Application to AIDS*, Biometrics.

**Examples**

```
data(hiv)
```

---

Icens-internal	<i>Internal Icens functions</i>
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---

**Description**

Internal Icens functions

**Details**

These are not to be called by the user.

---

icsurv	<i>The class of objects returned by the estimation routines in the Icens library.</i>
--------	---

---

**Description**

An object of class `icsurv` must contain the following components:

**converge** A boolean indicating whether the iteration producing `pf` converged.

**pf** The probability vector.

It can optionally contain any of the following components:

**clmat** The clique matrix used to obtain `pf`.

**intmap** The real representations of the support for the components of `pf`.

**iter** A matrix containing every iterative estimate of `pf`, useful for debugging.

**lval** The value of the **log** likelihood at `pf`.

**numiter** The number of iterations taken.

**sigma** The cumulative sum of `pf`.

**weights** Weights used in the EMICM algorithm.

**Author(s)**

Alain Vandal and Robert Gentleman.

**See Also**

[VEM](#), [ISDM](#), [EMICM](#), [PGM](#), [EM](#)

---

 ISDM

*Estimate the NPMLE of censored data using the ISDM method proposed in Lesperance and Kalbfleisch (19*

---

### Description

ISDM is a method for estimating the NPMLE of censored data.

### Usage

```
ISDM(A, pvec, maxiter=500, tol=1e-07, tolbis=1e-08, verbose=FALSE)
```

### Arguments

A	The m by n incidence, or clique, matrix. Or the n by 2 matrix containing the event intervals.
pvec	An initial estimate of the probability vector; not required.
maxiter	Maximum number of iterations to be made.
tol	The tolerance used to determine convergence.
tolbis	A second tolerance used for the steps.
verbose	Boolean, should verbose output be printed.

### Details

Lots of complicated stuff should go here.

### Value

A list containing:

pf	The estimated NPMLE of the probability vector.
numiter	The number of iterations performed.

### Author(s)

Alain Vandal and Robert Gentleman

### References

An Algorithm for Computing the Nonparametric MLE of a Mixing Distribution, Lesperance, Mary L. and Kalbfleisch, John D., JASA, 1992

### See Also

[VEM](#), [EMICM](#), [PGM](#)

**Examples**

```
data(cosmesis)
csub1 <- subset(cosmesis, subset=Trt==0, select=c(L,R))
ISDM(csub1)
# data(pruitt)
# ISDM(pruitt)
```

---

**Maclist***A function to*

---

**Description**

Returns a list of maximal cliques of the intersection graph of the real valued intervals supplied in *m*. These are one dimensional intervals with one interval for each individual. The algorithm is coded in interpreted code and should be moved to compiled code for speed. How do we handle exact failure times? Which algorithm is used?

**Usage**

```
Maclist(intvls, Lopen=TRUE, Ropen=FALSE)
```

**Arguments**

<i>intvls</i>	A <i>n</i> by 2 matrix, the first column is the left endpoints and the second column contains the right endpoints of the failure time intervals.
<i>Lopen</i>	A boolean indicating whether the intervals are open on the left.
<i>Ropen</i>	A boolean indicating whether the intervals are open on the right.

**Value**

A list of length *m*. Each element of the list corresponds to one maximal antichain. The row numbers (from *m*) identify the individuals and all row numbers for the individuals in the maximal clique. Maximal cliques occur in their natural (left to right) order.

**Author(s)**

Alain Vandal and Robert Gentleman

**References**

Computational Methods for Censored Data using Intersection Graphs, R. Gentleman and A. Vandal, JCGS, 2000.

**See Also**

[Macmat](#)

**Examples**

```
data(cosmesis)
csub1 <- subset(cosmesis, subset=Trt==0, select=c(L,R))
ml1 <- Maclist(csub1)
```

---

**Macmat***A function to compute the incidence matrix for an intersection graph.*

---

**Description**

Returns the Petrie matrix and Petrie pairs of an interval order given its list of maximal antichains. These can be obtained from [Maclist](#).

**Usage**

```
Macmat(ml)
```

**Arguments**

**ml** A list containing the maximal cliques of the intersection graph of the data.

**Details**

Not worth mentioning?

**Value**

A list containing two components.

**pmat** The Petrie or clique matrix of the underlying interval order.

**ppairs** The Petrie pairs for each observation. These indicate the first and last maximal clique occupied by the observation.

**Author(s)**

Alain Vandal and Robert Gentleman

**References**

Computational Methods for Censored Data using Intersection Graphs, R. Gentleman and A. Vandal, JCGS, 2000.

**See Also**

[Maclist](#)

**Examples**

```
data(cosmesis)
csub1 <- subset(cosmesis, subset=Trt==0, select=c(L,R))
ml1 <- Maclist(csub1)
mm1 <- Macmat(ml1)
```

---

**MLEintvl***Compute the real representation for the maximal cliques.*

---

**Description**

The intervals on the real line that corresponds to the intersections of the maximal cliques are computed and returned.

**Usage**

```
MLEintvl(intvls, ml=Maclist(intvls))
```

**Arguments**

<code>intvls</code>	The $n$ by 2 matrix containing the event time intervals for the individuals under study.
<code>ml</code>	The <a href="#">Maclist</a> computed for the <code>intvls</code> .

**Value**

An  $m$  by 2 matrix, where  $m$  is the number of maximal cliques. The first column contains the left end point of the real representation for the appropriate maximal clique and the second column contains the right end point.

**Author(s)**

Alain Vandal and Robert Gentleman

**References**

Computational Methods for Censored Data using Intersection Graphs, R. Gentleman and A. Vandal, JCGS, 2000.

**See Also**

[Maclist](#)

**Examples**

```
data(cosmesis)
csub1 <- subset(cosmesis, subset=Trt==0, select=c(L,R))
MLEintvl(csub1)
```

---

PGM	<i>An implementation of the projected gradient methods for finding the NPMLE.</i>
-----	---

---

### Description

An estimate of the NPMLE is obtained by using projected gradient methods. This method is a special case of the methods described in Wu (1978).

### Usage

```
PGM(A, pvec, maxiter = 500, tol=1e-07, told=2e-05, tolbis=1e-08,
    keepiter=FALSE)
```

### Arguments

A	A is either the m by n clique matrix or the n by 2 matrix containing the left and right end points for each event time.
pvec	An initial estimate of the probability vector.
maxiter	The maximum number of iterations to take.
tol	The tolerance for decreases in likelihood.
told	told does not seem to be used.
tolbis	The tolerance used in the bisection code.
keepiter	A boolean indicating whether to return the number of iterations.

### Details

New directions are selected by the projected gradient method. The new optimal pvec is obtained using the bisection algorithm, moving in the selected direction. Convergence requires both the  $L_1$  distance for the improved pvec and the change in likelihood to be below tol.

### Value

An object of class `icsurv` containing the following components:

pf	The NPMLE of pvec.
sigma	The cumulative sum of pvec.
lval	The value of the log likelihood at pvec.
clmat	The clique matrix.
method	The method used, currently only "MPGM" is possible.
lastchange	The difference between pf and the previous iterate.
numiter	The number of iterations carried out.
eps	The tolerances used.
converge	A boolean indicating whether convergence occurred within maxiter iterations.
iter	If keepiter is true then this is a matrix containing all iterations - useful for debugging.



**Author(s)**

Alain Vandal and Robert Gentleman.

**References**

*Some Algorithmic Aspects of the Theory of Optimal Designs*, C.-F. Wu, 1978, Annals.

**See Also**

[VEM](#), [ISDM](#), [EMICM](#), [PGM](#), [EM](#)

**Examples**

```
data(cosmesis)
csub1 <- subset(cosmesis, subset=Trt==0, select=c(L,R))
PGM(csub1)
data(pruitt)
PGM(pruitt)
```

---

plot.icsurv	<i>A plot method for the estimates produced by the estimation methods in Icms.</i>
-------------	--

---

**Description**

Produces nice plots of the estimated NPMLE.

**Usage**

```
## S3 method for class 'icsurv'
plot(x, type="eq", surv=FALSE, bounds=FALSE, shade=3, density=30,
     angle=45, lty=1, new=TRUE, xlab="Time", ylab="Probability", main="GMLE",
     ltybnds=2, ...)
```

**Arguments**

x	The estimate of the NPMLE.
type	Three options, "eq" for equivalence call, "gw" for the Groeneboom-Wellner estimate, and "lc" for the left-continuous estimate.
surv	Logical indicating whether or not to plot the survival curve.
bounds	Logical indicating whether or not to include bounds around the estimate.
shade	An integer in 1, 2, or 3 denoting what component of the plot to shade.
density	The density of shading lines, in lines per inch.
angle	The slope of shading lines, given as an angle in degrees (counter-clockwise).
lty	The line type for the estimates.

<code>new</code>	Logical indicating whether or not to create a new plot.
<code>xlab</code>	The x-axis label.
<code>ylab</code>	The y-axis label.
<code>main</code>	The main title for the plot.
<code>ltybnds</code>	The line type for the bounds on the estimates.
<code>...</code>	Additional arguments passed to the plot function.

**Value**

No value is returned. A plot of the NPMLE is made on the active graphics device.

**Author(s)**

Alain Vandal and Robert Gentleman.

**See Also**

[VEM](#), [ISDM](#), [EMICM](#), [PGM](#)

**Examples**

```
data(cosmesis)
csub1 <- subset(cosmesis, subset=Trt==0, select=c(L,R))
e1 <- VEM(csub1)
par(mfrow=c(2,2))
plot(e1)
data(pruitt)
e2 <- EM(csub1)
plot(e2)
e3 <- PGM(csub1)
plot(e3)
e4 <- EMICM(csub1)
plot(e4)
```

---

Plotboxes

*Plot the event time regions for bivariate data.*

---

**Description**

Plot rectangles described by the interval given in the first two arguments.

**Usage**

```
Plotboxes(int1, int2, textp=FALSE, showmac=FALSE, showsupp=FALSE, showmp=FALSE,
cliques=NULL, macprod=NULL, density=c(2, 8, 20), col=c(2, 3, 4),
offsetx=0.02, offsety=0.03)
```

**Arguments**

int1	The intervals for the x dimension.
int2	The intervals for the y dimension.
textp	Boolean, if true add text.
showmac	Boolean, if true then the maximal cliques are shown in a different color?
showsupp	Boolean, if true show support boxes.
showmp	Boolean
cliques	Maximal cliques.
macprod	macprod
density	The density of the polygon shading lines, in lines per inch.
col	Color for plotting features.
offsetx	Offset for x-axis.
offsety	Offset for y-axis.

**Value**

No value is returned. The event rectangles are plotted on the active graphics device.

**Author(s)**

A. Vandal and R. Gentleman

**References**

*Graph-Theoretical Aspects of Bivariate Censored Data*, R. Gentleman and A. Vandal, 1999, submitted.

**See Also**

[BVclmat](#), [BVsupport](#), [BVcliques](#)

**Examples**

```
data(cmV)
Plotboxes(cmV[,1:2], cmV[,3:4], showmac=TRUE)
```

---

PMGA

*Implement the pool monotone groups algorithm.*

---

### Description

For isotonization problems some increase in speed and decrease in complexity can be achieved through the use of the pool monotone groups algorithm of Y.L. Zhang and M.A. Newton (1997). It isotonizes a weighted and ordered set of values.

### Usage

```
PMGA(est, ww=rep(1, length(est)))
```

### Arguments

est	The vector of values, in the appropriate order.
ww	The weight vector.

### Details

To be supplied at some later date.

### Value

An object containing the following components:

est	The isotonized estimates.
ww	The weights associated with the isotonized estimates.
poolnum	The number of values pooled in the current estimate.
passes	The number of passes which were required to isotonize the list.

### Author(s)

Alain Vandal and Robert Gentleman.

### References

Y.L. Zhang and M.A. Newton (1997), <http://www.stat.wisc.edu/~newton/newton.html>)

### See Also

[EMICM](#)

---

pruitt                      *A small artificial, bivariate right-censored data set.*

---

### Description

The pruitt data was given in Pruitt (1993) as an example for testing different methods of estimating the bivariate NPMLE for right censored data. This matrix represents the clique matrix of the intersection graph of the data set given by Pruitt.

### Format

This data frame contains 8 columns, labeled A through H that represent the observations. There are seven rows corresponding to the seven maximal cliques in the intersection graph.

### Source

Small Sample Comparison of Six Bivariate Survival Curve Estimators, Journal of Statistical Computation and Simulation, R. Pruitt, 1993.

### Examples

```
data(pruitt)
```

---

VEM                              *Compute the NPMLE of p via the Vertex Exchange Method.*

---

### Description

The Vertex Exchange Method is used to obtain the NPMLE of p.

### Usage

```
VEM(A, pvec, maxiter=500, tol=1e-07, tolbis=1e-07, keepiter=FALSE)
```

### Arguments

A	The m by n incidence matrix or the n by 2 matrix of intervals.
pvec	The initial estimate for the probability vector.
maxiter	The maximum number of iterations allowed.
tol	The tolerance used to determine convergence.
tolbis	The tolerance used in the bisection stage of the algorithm.
keepiter	Should iteration information be retained and returned.

**Details**

Lots.

**Value**

An object of class `icsurv` with the following components.

<code>pf</code>	The NPMLE of the probability vector.
<code>numiter</code>	The number of iterations used.
<code>lval</code>	The value of the logarithm of the likelihood at the NPMLE.
<code>converge</code>	Boolean stating whether the iteration converged.
<code>intmap</code>	If present it contains the real representations for the maximal cliques. These are the intervals (on the real line) where the mass in <code>pf</code> is placed.

**Author(s)**

Robert Gentleman and Alain Vandal

**References**

*A Vertex-exchange-method in  $SD$ -optimal Design Theory*, D. Bohning, *Metrika*, 1986.

**See Also**

[EM](#), [ISDM](#), [EMICM](#), [PGM](#)

**Examples**

```
data(cosmesis)
csub1 <- subset(cosmesis, subset=Trt==0, select=c(L,R))
VEM(csub1)
data(pruitt)
VEM(pruitt)
```

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