

Package ‘etasFLP’

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Type Package

Title Mixed FLP and ML Estimation of ETAS Space-Time Point Processes

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Description Estimation of the components of an ETAS model for earthquake description. Non-parametric background seismicity can be estimated through FLP (Forward Likelihood Predictive), while parametric components are estimated through maximum likelihood. The two estimation steps are alternated until convergence is obtained. For each event the probability of being a background event is estimated and used as a weight for declustering steps. Many options to control the estimation process are present, together with some diagnostic tools. Some descriptive functions for earthquakes catalogs are present; also plot, print, summary, profile methods are defined for main output (objects of class 'etasclass').

License GPL (>= 2)

Imports fields,maps

Depends R (>= 2.14.0),mapdata,rgl

Suggests MASS

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etasFLP-package	<i>Mixed FLP and ML Estimation of ETAS Space-Time Point Processes</i>
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Description

Estimation of the components of an ETAS model for earthquake description. Non-parametric background seismicity can be estimated through FLP (Forward Likelihood Predictive), while parametric components are estimated through maximum likelihood. The two estimation steps are alternated until convergence is obtained. For each event the probability of being a background event is estimated and used as a weight for declustering steps. Many options to control the estimation process are present, together with some diagnostic tools. Some descriptive functions for earthquakes catalogs are present; also plot, print, summary, profile methods are defined for main output (objects of class etasclass)

Details

Package:	etasFLP
Type:	Package
Version:	1.3.0
Date:	2015-06-03
License:	GPL (>=2)
Depends:	R (>= 2.14.0), mapdata,rgl
Suggests:	MASS

etasclass is the main function of the package etasFLP.

Note

The package is intended for the estimation of the ETAS model for seismicity description (introduced by Ogata (1988), see reference), but theoretically it can be used for other fields of application.

Author(s)

Marcello Chiodi and Giada Adelfio

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References

Adelfio, G. and Chiodi, M. (2013) Mixed estimation technique in semi-parametric space-time point processes for earthquake description. *Proceedings of the 28th International Workshop on Statistical Modelling 8-13 July, 2013, Palermo* (Muggeo VMR, Capursi V, Boscaino G, Lovison G, editors). Vol. 1. pp.65-70.

Adelfio, G. and Chiodi, M. (2015) Alternated estimation in semi-parametric space-time branching-type point processes with application to seismic catalogs. *Stochastic Environmental Research and Risk Assessment* DOI: 10.1007/s00477-014-0873-8 **29**(2), pp. 443-450.

Chiodi, M. and Adelfio, G., (2011) Forward Likelihood-based predictive approach for space-time processes. *Environmetrics*, vol. **22** (6), pp. 749-757.

Console, R., Jackson, D. D. and Kagan, Y. Y. Using the ETAS model for Catalog Declustering and Seismic Background Assessment. *Pure Applied Geophysics* **167**, 819–830 (2010).

Ogata, Y. Statistical models for earthquake occurrences and residual analysis for point processes. *Journal of the American Statistical Association*, **83**, 9–27 (1988).

Veen, A. and Schoenberg, F.P. Estimation of space-time branching process models in seismology using an EM-type algorithm. *Journal of the American Statistical Association*, **103**(482), 614–624 (2008).

Zhuang, J., Ogata, Y. and Vere-Jones, D. Stochastic declustering of space-time earthquake occurrences. *Journal of the American Statistical Association*, **97**, 369–379 (2002).

b.guten

Estimates the parameter of the Gutenberg-Richter law.

Description

Estimates the parameter of the Gutenberg-Richter law for the magnitude distribution of earthquakes, given a threshold magnitude; it uses moment estimator on transformed data.

Usage

```
b.guten(magn, m0=min(magn))
```

Arguments

magn	a vector of magnitudes coming from an earthquake catalog.
m0	A threshold value. Only values of magn not less than m0 will be used.

Details

Maximum likelihood estimation for the Gutenberg-Richter Law:

$$\log_{10} N(> m) = a - b M$$

where $N(> m)$ is the number of events exceeding a magnitude m and a, b are two parameters: a is related to the total seismicity rate of the region while b , to be estimated, should be usually near 1.

Catalog is assumed to be complete (in a certain space-time region) at least for a magnitude m_0 , that is, every earthquake of magnitude at least m_0 in that space-time region, is certainly present in the catalog.

Value

b	estimate of the parameter b of the Gutenberg-Richter Law.
se	estimate of the standard error of the estimate b .

Note

the plot produced by `magn.plot` can be used to have an idea, for a given catalog, of the magnitude threshold value.

Author(s)

Marcello Chiodi

References

Gutenberg, B. and Richter, C. F. (1944). Frequency of earthquakes in California. *Bulletin of the Seismological Society of America*, 34, 185-188.

See Also

[magn.plot](#)

Examples

```
data(italycatalog)
b.guten(italycatalog$magn1)
```

`bwd.nrd`*Silverman's rule optimal for the estimation of a kernel bandwidth*

Description

Computes the optimal bandwidth with the Silverman's rule of thumb, to be used for a kernel estimator with given points and weights.

Usage

```
bwd.nrd(x, w=replicate(length(x),1), d = 2)
```

Arguments

<code>x</code>	numeric vector: sample points to be used for a normal kernel estimator.
<code>w</code>	numeric vector of the same length of <code>x</code> : weights to give to the elements of <code>x</code> . Default is a vector of ones
<code>d</code>	number of dimensions of the kernel estimator.

Details

Computes the optimal bandwidth with the Silverman rule, for a kernel estimator with points `x` and weights `w`. If a multivariate kernel is used, (i.e. $d > 1$), `bwd.nrd` must be called for each variable. It computes dispersion only with the weighted standard deviation, with no robust alternative. Called by `kde2dnew.fortran`.

Value

The value of the bandwidth for a sample `x` and weights `w`.

Note

It is used in connection with the the declustering method of `etasFLP`. Points with an higher probability of being part of the background seismicity will weight more in the estimation of the background seismicity.

Note

This is a slight modification of [bw.nrd](#).

Author(s)

Marcello Chiodi

References

Silverman, B.W. (1986). *Density Estimation for Statistics and Data Analysis*. Chapman and Hall: London.

Examples

```
## Not run:
## The function is currently defined as
function (x,w=replicate(length(x),1),d=2)
{
  if (length(x) < 2L)
    stop("need at least 2 data points")
  m<-weighted.mean(x,w)
  return(sqrt(weighted.mean((x-m)^2,w)) *
    (length(x)*(d+2)/4)^(-1/(d+4)))
}

## End(Not run)
```

californiacatalog *Sample catalog of North California earthquakes*

Description

Sample catalog of North California earthquakes of magnitude at least 3.0 from year 1968 to year 2012.

Usage

```
californiacatalog
```

Format

a data matrix with 18,545 observations and 5 variables: time, lat, long, z, magn1.

Source

Northern California Earthquake Data Center.

References

Northern California Earthquake Catalog Search: <http://www.ncedc.org/ncedc/catalog-search.html>.

Examples

```
data(californiacatalog)
str(californiacatalog)
```

compare.etasclass *Compare two etasclass objects*

Description

Compare the results of two etasclass executions through the comparison of some elements of two etasclass objects.

Usage

```
compare.etasclass(etas1,etas2)
```

Arguments

etas1	an etasclass object.
etas2	an etasclass object.

Details

Compare the results of two etasclass executions through the comparison of some elements of two etasclass objects. Fundamental elements (catalog, threshold magnitude) should be equal, but no check is made

Value

params	Standardized comparison of the estimated parameters.
AIC	Difference of AIC values.
weights	Comparison of the weights rho.weights of the two input objects.
rho.weights	Standardized comparison of the weights rho.weights of the two input objects.
cor.weights	Correlation between the weights rho.weights of the two input objects
cor.trig	Correlation between the triggered intensities of the two input objects
cor.back	Correlation between the background intensities of the two input objects

Author(s)

Marcello Chiodi

See Also

[etasclass](#)

 eqcat

Check earthquake catalog

Description

Preliminary check of the names of an earthquake catalog. `summary` and `plot` methods for earthquake catalogs.

Usage

```
eqcat(x)
## S3 method for class 'eqcat'
plot(x,...)
## S3 method for class 'eqcat'
summary(object,extended=TRUE,...)
```

Arguments

<code>x</code>	an earthquake catalog.
<code>object</code>	an eqcat object.
<code>extended</code>	if TRUE some extra summary functions are computed.
<code>...</code>	other arguments.

Details

Minimal check of an earthquake catalog; checks only if it is suitable for the use as argument of the functions of `etasFLP` (mainly `etasclass`); checks only the presence of variables with the names `time`, `lat`, `long`, `z`, `magn1`. `summary` and `plot` methods are defined for earthquake catalogs.

Value

If the catalog passes the check, then the catalog is returned with the new class name `eqcat`; otherwise an error message is printed.

<code>cat</code>	a catalog is returned. If the check is ok, this is an eqcat class object.
<code>ok</code>	A flag: TRUE if the check is ok; FALSE elsewhere.

Note

In this first version if you have a catalog without the depth (`z`), please insert however a constant column. The depth can be used only in some plot and not in the estimation routines of the package `etasFLP`; `etasclass` uses only `time`, `lat`, `long`, `magn1`.

Author(s)

Marcello Chiodi

See Also[etasclass](#)**Examples**

```
data(italycatalog)
f=eqcat(italycatalog)
print(f$ok)
```

etas.starting	<i>Guess starting values of ETAS parameters (beta-version). Only from package version 1.2.0</i>
---------------	---

Description

etas.starting is a simple function to give starting values of the 8 ETAS parameters for the function etasclass.

It gives only rough approximation, based on some assumptions, intended to give only the order of magnitude of each parameter (but should be better than nothing). Returns a list with 8 starting values. With this beta-version user must give manually the output of this function in the input of etasclass

Usage

```
etas.starting(cat.orig,
m0=2.5,
p.start=1,
a.start=1.5,
gamma.start=0.5,
q.start=2,
longlat.to.km=TRUE,
sectoday=TRUE
)
```

Arguments

cat.orig	An earthquake catalog, possibly an object of class eqcat, or however a data.frame with variables of names time, lat, long, z, magn1. No missing values are allowed.
m0	Threshold magnitude (only events with a magnitude at least magn.threshold will be used). Default value = 2.5.
p.start	Parameter 4 of the ETAS model; the exponent of the Omori law for temporal decay rate of aftershocks; see details. Default value = 1.0.
a.start	Parameter 5 (α) of the ETAS model; efficiency of an event of given magnitude in generating aftershocks; see details. Default value = 1.5.

<code>gamma.start</code>	Parameter 6 (γ) of the ETAS model; together with <code>a</code> is related to the efficiency of an event of given magnitude in generating aftershocks; see details. Default value = 0.5.
<code>q.start</code>	Parameter 8 of the ETAS model; parameter related to the spatial influence of the mainshock; see details. Default value = 2.
<code>sectoday</code>	if TRUE, then time variable of <code>cat.orig</code> is converted from seconds to days. Default value = TRUE.
<code>longlat.to.km</code>	if TRUE, then <code>long</code> and <code>lat</code> variables of <code>cat.orig</code> are treated as geographical coordinates and converted to kilometers. Default value = TRUE.

Details

It is a beta-version of a very crude method to give starting values for the eight parameters of an ETAS (Epidemic type aftershock sequences) model for the description of the seismicity of a space-time region. These starting values can be used as input for the function `etasclass` `sectoday` and `longlat.to.km` flags must be the same that will be used in `etasclass`.

In this first attempt to give starting values for the ETAS model, many approximations are used

It gives only rough approximation, based on some assumptions, intended to give only the order of magnitude of each parameter (but it should be better than nothing). It returns a list with 8 starting values. With this beta-version user must give manually the output of this function in the input of `etasclass`.

The values of `p.start`, `a.start`, `gamma.start` and `q.start` must be however given by the user (we did not find anything reasonable). Default choices for `p` and `q` (`p.start=1`, `q.start=2`) are strongly recommended.

`c` and `d` are estimated from the empirical distributions of time differences and space distances, respectively. `mu` and `k0` are then estimated from the starting values of the other six parameters, solving the two ML equations, that is derivatives of the whole likelihood with respect to `mu` and `k0` equated to zero. In the computation of the likelihood an approximation for the integral of the intensity function is used (quoted also in Schoenberg (2013)).

Value

returns a list:

<code>mu.start</code>	guess value for <code>mu</code>
<code>k0.start</code>	guess value for <code>k0</code>
<code>c.start</code>	guess value for <code>c</code>
<code>p.start</code>	guess value for <code>p</code> (the same as input value)
<code>a.start</code>	guess value for <code>a</code> (the same as input value)
<code>gamma.start</code>	guess value for <code>gamma</code> (the same as input value)
<code>d.start</code>	guess value for <code>d</code>
<code>q.start</code>	guess value for <code>q</code> (the same as input value)
<code>longlat.to.km</code>	<code>longlat.to.km</code> (the same as input value)
<code>sectoday</code>	<code>sectoday</code> (the same as input value)

Note

The optimization algorithm used in `etasclass` depends on the choice of initial values. Some default guess choice is performed in the present beta-version of the function `etas.starting`. If convergence problem are experienced, a useful strategy can be to start with an high magnitude threshold value m_0 (that is, with a smaller catalog with bigger earthquakes), and then using this first output as starting guess for a running with a lower magnitude threshold value m_0 . In this trial executions avoid declustering (`declustering=FALSE`) or at least use a small value of `ndeclust`; small values of `iterlim` and `ntheta` can speed first executions.

Quicker executions are obtained using smaller values of `iterlim` and `ntheta` in the input.

Also a first execution with `is.backconstant = TRUE`, to fit a first approximation model with constant background, can be useful.

Some other useful information can be obtained estimating a pure time process, that can give a good guess at least for some parameters, like $\mu, \kappa_0, \alpha, c, p$.

Input times are expected in days, and so final intensities are expected number of events per day. If input values are in seconds, then set `sectoday=TRUE`

Author(s)

Marcello Chiodi, Giada Adelfio

References

Schoenberg, F. P. (2013).Facilitated Estimation of ETAS. *Bulletin of the Seismological Society of America*, Vol. 103, No. 1, pp. 601-605, February 2013, doi: 10.1785/0120120146

See Also

[etasclass](#)

etasclass

Mixed estimation of an ETAS model

Description

`etasclass` is the main function of the package `etasFLP`.

Performs the estimation of the components of the ETAS (Epidemic type aftershock sequences) model for the description of the seismicity in a space-time region. Background seismicity is estimated non-parametrically, while triggered seismicity is estimated by MLE. In particular also the bandwidth for a kernel smoothing can be estimated through the Forward Likelihood Predictive approach (FLP). For each event the probability of being a background event or a triggered one is estimated.

An ETAS with up to 8 parameters can be estimated, with several options and different methods.

Returns an `etasclass` object, for which `plot`, `summary`, `print` and `profile` methods are defined.

Usage

```

etasclass(cat.orig,
  magn.threshold=2.5, magn.threshold.back=magn.threshold+2,
  mu=1,k0=1,c=0.5,p=1.01,a=1.2,gamma=.5,d=1.,q=1.5, params.ind=replicate(8,TRUE),

  hdef=c(1,1),
declustering=TRUE,thinning=FALSE,
  flp=TRUE, m1=NULL, ndeclust=5, onlytime=FALSE,is.backconstant=FALSE,
  w=replicate(nrow(cat.orig),1),
##### end of main input arguments.
##### Control and secondary arguments:
  description="", cat.back=NULL, back.smooth=1.0,
  sectoday=TRUE,longlat.to.km=TRUE,
  usenlm=TRUE, method ="BFGS", compsqm=TRUE,
  epsmax=0.0001, iterlim=100, ntheta=100)

```

Arguments

cat.orig	An earthquake catalog, possibly an object of class eqcat, or however a data.frame with variables of names time, lat, long, z, magn1. No missing values are allowed.
magn.threshold	Threshold magnitude (only events with a magnitude at least magn.threshold will be used). Default value = 2.5.
magn.threshold.back	Threshold magnitude used to build the catalog cat.back for the first estimation of the background seismicity. Default value = magn.threshold+2. <i>Values for the 8 parameters of the ETAS model (starting values or fixed values according to params.ind):</i>
mu	Parameter 1 (μ) of the ETAS model: background general intensity; see details. Default value = 1.
k0	Parameter 2 (κ_0) of the ETAS model: measures the strength of the aftershock activity; see details. Default value = 1.
c	Parameter 3 of the ETAS model; a shift parameter of the Omori law for temporal decay rate of aftershocks; see details. Default value = 0.5.
p	Parameter 4 of the ETAS model; the exponent of the Omori law for temporal decay rate of aftershocks; see details. Default value = 1.01.
a	Parameter 5 (α) of the ETAS model; efficiency of an event of given magnitude in generating aftershocks; see details. Default value = 1.2.
gamma	Parameter 6 (γ) of the ETAS model; together with a is related to the efficiency of an event of given magnitude in generating aftershocks; see details. Default value = 0.5.
d	Parameter 7 of the ETAS model; parameter related to the spatial influence of the mainshock; see details. Default value = 1.
q	Parameter 8 of the ETAS model; parameter related to the spatial influence of the mainshock; see details. Default value = 1.5.

End of model parameter input

params.ind	vector of 8 logical values: params.ind[i] = TRUE means that the i-th parameter must be estimated. params.ind[i] = FALSE means that the i-th parameter is fixed to its input value (the order of parameters is: mu, k0, c, p, a, gamma, d, q). Default value = replicate(8,TRUE), that is, etasclass estimates all parameters. <i>Flags for the kind of declustering and smoothing:</i>
hdef	Starting values for the x,y bandwidths used in the kernel estimator of background seismicity. Default value = 1,1.
declustering	if TRUE the catalog is iteratively declustered to optimally estimate the background intensity (through thinning, if thinning=TRUE, or through weighting if thinning=FALSE). Default value = TRUE.
thinning	if thinning=TRUE a background catalog is obtained sampling from the original catalog with probabilities estimated during the iterations. Default value =FALSE.
flp	if flp=TRUE then background seismicity is estimated through Forward Likelihood Predictive (see details). Otherwise the Silverman rule is used. Default value =TRUE.
m1	Used only if flp=TRUE. Indicates the range of points used for the FLP steps. See details. If missing it is set to nrow(cat)/2.
ndeclust	maximum number of iterations for the general declustering procedure. Default=5.
onlytime	if TRUE then a time process is fitted to data, regardless to space location (in this case is.backconstant is set to TRUE and declustering, flp are set to FALSE). Default value = FALSE.
is.backconstant	if TRUE then background seismicity is assumed to be homogeneous in space (and declustering, flp are set to FALSE). Default value = FALSE.
w	initial weights <i>Other control parameters:</i>
description	a description string used for the output. Default value = "".
cat.back	external catalog used for the estimation of the background seismicity. Default value = NULL.
back.smooth	Controls the level of smoothing for the background seismicity (meaningful only if flp=FALSE). Default value = 1.
sectoday	if TRUE, then time variable of cat.orig is converted from seconds to days. Default value = TRUE.
longlat.to.km	if TRUE, then long and lat variables of cat.orig are treated as geographical coordinates and converted to kilometers. Default value = TRUE.
usenlm	if TRUE, then nlm function (gauss-newton method) is used in the maximum likelihood steps; if FALSE, then optim function is used (with method =method). Default value = TRUE.
method	used if usenlm=FALSE: method used by optim. Default value = "BFGS".
compsqm	if TRUE, then standard errors are computed. Default value = TRUE.
epsmax	maximum allowed difference between estimates in subsequent iterations (default = 0.0001).

<code>iterlim</code>	maximum number of iterations in the maximum likelihood steps (used in <code>nlm</code> or <code>optim</code>). Default value = 100.
<code>ntheta</code>	number of subdivisions of the round angle, used in the approximation of the integral involved in the likelihood computation of the ETAS model. Default value = 100.

Details

Estimates the components of an ETAS (Epidemic type aftershock sequences) model for the description of the seismicity of a space-time region. Background seismicity is estimated nonparametrically, while triggered seismicity is estimated by MLE.

The bandwidth of the kernel density estimator is estimated through the Forward Likelihood Predictive approach (FLP), (theoretical reference on Adelfio and Chiodi, 2013) if `flp` is set to `TRUE`. Otherwise the bandwidth is estimated through Silverman's rule. FLP steps for the estimation of nonparametric background component is alternated with the Maximum Likelihood step for the estimation of parametric components (only if `declustering=TRUE`). For each event the probability of being a background event or a triggered one is estimated, according to a declustering procedure in a way similar to the proposal of Zhuang, Ogata, and Vere-Jones (2002).

The ETAS model for conditional space time intensity $\lambda(x, y, t)$ is given by:

$$\lambda(x, y, t) = \mu f(x, y) + \sum_{t_j < t} \frac{\kappa_0 e^{(\alpha-\gamma)(m_j-m_0)}}{(t-t_j+c)^p} \left\{ \frac{(x-x_j)^2 + (y-y_j)^2}{e^{\gamma(m_j-m_0)}} + d \right\}^{-q}$$

$f(x, y)$ is estimated through a weighted kernel gaussian estimator; if `flp` is set to `TRUE` then the bandwidth is estimated through a FLP step.

Weights (computed only if `declustering=TRUE`) are given by the estimated probabilities of being a background event; for the i -th event this is given by $\rho_i = \frac{\mu f(x_i, y_i)}{\lambda(x_i, y_i, t_i)}$. The weights ρ_i are updated after a whole iteration.

μ (μ) measures the background general intensity (which is assumed temporally homogeneous);

κ_0 (κ_0) is a scale parameter related to the importance of the induced seismicity;

c and p are the characteristic parameters of the seismic activity of the given region; c is a shift parameter while p , which characterizes the pattern of seismicity, is the exponent parameter of the modified Omori law for temporal decay rate of aftershocks;

α (α) and γ (γ) measure the efficiency of an event of given magnitude in generating aftershock sequences;

d and q are two parameters related to the spatial influence of the mainshocks.

Many kinds of ETAS models can be estimated, managing some control input arguments. The eight ETAS parameters can be fixed to some input value, or can be estimated, according to `params.ind`: if `params.ind[i]=FALSE` the i -th parameter is kept fixed to its input value, otherwise, if `params.ind[i]=TRUE`, the i -th parameter is estimated and the input value is used as a starting value.

By default `params.ind=c(TRUE, TRUE, TRUE, TRUE, TRUE, TRUE, TRUE, TRUE)`, and so a full 8 parameters ETAS model will be estimated.

The eight parameters are internally ordered in this way: `params = (mu, k0, c, p, a, gamma, d, q)`; for example a model with a fixed value $p=1$ (and `params.ind[4]=FALSE`) can be estimated and compared with the model where p is estimated (`params.ind[4]=TRUE`);

for example a 7 parameters model can be fitted with `gamma=0` and `params.ind[6]=FALSE`, so that input must be in this case: `params.ind=c(TRUE, TRUE, TRUE, TRUE, TRUE, FALSE, TRUE, TRUE)`;

if `onlytime=TRUE` a time process is fitted to data (with a maximum of 5 parameters), regardless to space location (however the input catalog `cat.orig` must contain three columns named `long`, `lat`, `z`);

if `is.backconstant=TRUE` a process (space-time or time) with a constant background intensity μ is fitted;

if `mu` is fixed to a very low value a process with very low background intensity is fitted, that is with only clustered intensity (useful to fit a model to a single cluster of events).

If `flp=TRUE` the bandwidth for the kernel estimation of the background intensity is evaluated maximizing the Forward Likelihood Predictive (FLP) quantity, given by (Chiodi, Adelfio, 2011; Adelfio, Chiodi, 2013):

$$FLP_{k_1, k_2}(\hat{\psi}) \equiv \sum_{k=k_1}^{n-1} \delta_{k, k+1}(\hat{\psi}(H_{t_k}); H_{t_{k+1}})$$

with $k_1 = \frac{n}{2}$, $k_2 = n - 1$ and where $\delta_{k, k+1}(\hat{\psi}(H_{t_k}); H_{t_{k+1}})$ is the *predictive information* of the first k observations on the $k + 1$ -th observation, and is so defined:

$$\delta_{k, k+1}(\hat{\psi}(H_{t_k}); H_{t_{k+1}}) \equiv \log L(\hat{\psi}(H_{t_k}); H_{t_{k+1}}) - \log L(\hat{\psi}(H_{t_k}); H_{t_k})$$

where H_k is the history of the process until time t_k and $\hat{\psi}(H_{t_k})$ is an estimate based only on history until the $k - th$ observation.

In the ML step, the vector of parameter $\theta = (\mu, \kappa_0, c, p, \alpha, \gamma, d, q)$ is estimated maximizing the sample log-likelihood given by:

$$\log L(\theta; H_{t_n}) = \sum_{i=1}^n \log \lambda(x_i, y_i, t_i; \theta) - \int_{T_0}^{T_{max}} \int \int_{\Omega(x, y)} \lambda(x, y, t; \theta) dx dy dt$$

Value

returns an object of class `etasclass`.

The main items of the output are:

<code>this.call</code>	reports the exact call of the function
<code>params.ind</code>	indicates which parameters have been estimated (see details)
<code>params</code>	ML estimates of the ETAS parameters.
<code>sqm</code>	Estimates of standard errors of the ML estimates of the ETAS parameters (<code>sqm[i]=0</code> if <code>params.ind[i]=FALSE</code> and for the situation where hessian is not computed or near to singularity).
<code>AIC.iter</code>	AIC values at each iteration.
<code>hdef</code>	final bandwidth used for the kernel estimation of background spatial intensity (however estimated, with <code>flp=TRUE</code> or <code>flp=FALSE</code>).

`rho.weights` Estimated probability for each event to be a background event (ρ).
`time.res` rescaled time residuals (for time processes only).
`params.iter` A matrix with estimates values at each iteration.
`sqm.iter` A matrix with the estimates of the standard errors at each iteration.
`rho.weights.iter`
A matrix with the values of `rho.weights` at each iteration.
`l` A vector with estimated intensities, corresponding to observed points

`summary`, `print` and `plot` methods are defined for an object of class `etasclass` to obtain main output.
A `profile` method (`profile.etasclass`) is also defined to make approximate inference on a single parameter

Note

In this first version the x-y space region, where the point process is defined, is a rectangle embedding the catalog values.

The optimization algorithm depends on the choice of initial values. Some default guess choice is performed inside the function for parameters without input starting values. If convergence problem are experienced, a useful strategy can be to start with an high magnitude threshold value m_0 (that is, with a smaller catalog with bigger earthquakes), and then using this first output as starting guess for a running with a lower magnitude threshold value m_0 . In this trial executions avoid declustering (`declustering=FALSE`) or at least use a small value of `ndeclust`; small values of `iterlim` and `ntheta` can speed first executions.

Quicker executions are obtained using smaller values of `iterlim` and `ntheta` in the input.

Also a first execution with `is.backconstant = TRUE`, to fit a first approximation model with constant background, can be useful.

Some other useful information can be obtained estimating a pure time process, that can give a good guess at least for some parameters, like μ , κ_0 , α , c , p .

Input times are expected in days, and so final intensities are expected number of events per day. If input values are in seconds, then set `sectoday=TRUE`

Author(s)

Marcello Chiodi, Giada Adelfio

References

Adelfio, G. and Chiodi, M. (2014) Alternated estimation in semi-parametric space-time branching-type point processes with application to seismic catalogs. *Stochastic Environmental Research and Risk Assessment*, doi=10.1007/s00477-014-0873-8

Adelfio, G. and Chiodi, M. (2013) Mixed estimation technique in semi-parametric space-time point processes for earthquake description. *Proceedings of the 28th International Workshop on Statistical Modelling 8-13 July, 2013, Palermo* (Muggeo V.M.R., Capursi V., Boscaino G., Lovison G., editors). Vol. 1. pp.65-70.

Chiodi, M. and Adelfio, G., (2011) Forward Likelihood-based predictive approach for space-time processes. *Environmetrics*, vol. 22 (6), pp. 749-757.

Zhuang, J., Ogata, Y. and Vere-Jones, D. Stochastic declustering of space-time earthquake occurrences. *Journal of the American Statistical Association*, **97**, 369–379 (2002).

See Also

[eqcat](#), [plot.etasclass](#), [summary.etasclass](#), [profile.etasclass](#)

Examples

```
## Not run:
data("italycatalog")
# load a sample catalog of the italian seismicity

etas.flp=etasclass(italycatalog,
  magn.threshold = 3.0, magn.threshold.back = 3.5,
  k0 = 0.005, c = 0.005, p = 1.01, a = 1.05, gamma = 0.6, q = 1.52, d = 1.1,
  params.ind = c(TRUE, TRUE, TRUE, TRUE, TRUE, TRUE, TRUE, TRUE),
  declustering = TRUE, thinning = FALSE, flp = TRUE, ndeclust = 15,
  onlytime = FALSE, is.backconstant = FALSE,
  description = "etas flp",sectoday = TRUE, usenlm = TRUE, epsmax = 0.001)
# execution of etasclass for events with minimum magnitude of 3.0.
# The events with magnitude at least 3.5 are used to build a first approximation
# for the background intensity function
# (magn.threshold.back=3.5)

# print method for the etasclass object
etas.flp
Call:
etasclass(cat.orig = italycatalog, magn.threshold = 3, magn.threshold.back = 3.5,
  k0 = 0.005, c = 0.005, p = 1.01, a = 1.05, gamma = 0.6, d = 1.1,
  q = 1.52, params.ind = c(TRUE, TRUE, TRUE, TRUE, TRUE, TRUE, TRUE,
  TRUE, TRUE), declustering = TRUE, thinning = FALSE, flp = TRUE,
  ndeclust = 15, onlytime = FALSE, is.backconstant = FALSE,
  description = "etas flp", sectoday = TRUE, usenlm = TRUE,
  epsmax = 0.001)

etas flp
Number of observations          2158
ETAS Parameters:
      mu      k0      c      p      a      gamma      d      q
0.355850 0.008373 0.009404 1.121630 1.509371 0.857945 1.915139 1.836391

# plot results with maps of intensities and diagnostic tools
plot(etas.flp)
```

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

```
italycatalog
```

```
Small sample catalog of italian earthquakes
```

Description

A small sample catalog of italian earthquakes of magnitude at least 3.0 from year 2005 to year 2013.

Usage

```
italycatalog
```

Format

a data matrix with 2,158 observations and 5 variables: time, lat, long, z, magn1.

Source

INGV (Istituto Nazionale di Geofisica e Vulcanologia) ISIDE Data Base.

References

INGV home page: <http://www.ingv.it>.

Examples

```
data(italycatalog)
str(italycatalog)
```

```
kde2dnew.fortran
```

```
A 2-d normal kernel estimator
```

Description

A simple and quick 2-d weighted normal kernel estimator, with fixed bandwidth and relative integral.

Usage

```

kde2dnew.fortran(xkern, ykern, gx, gy, h, factor.xy = 1, eps=0, w =
  replicate(length(xkern), 1)

)

kde2d.integral(xkern, ykern, gx = xkern, gy = ykern, eps = 0, factor.xy = 1,
h = c(bwd.nrd(xkern, w), bwd.nrd(ykern, w)),
w = replicate(length(xkern), 1), wmat=numeric(0)

)

```

Arguments

xkern	x-values of kernel points of length n (n=length(xkern)).
ykern	y-values of kernel points of length n.
gx	x-values of the points where densities must be estimated.
gy	y-values of the points where densities must be estimated.
h	bandwidths: a length 2 numerical vector.
factor.xy	expansion factor for bandwidths (density will be smoother if factor.xy>1).
w	vector of weights to give to observed points (length n).
wmat	if kern.var=TRUE defines the variable metric
eps	enlargement factor for the region of interest.

Details

A standard bivariate normal kernel estimator.

Value

grid values and estimated densities.

Author(s)

Marcello Chiodi.

References

Venables, W. N. and Ripley, B. D. (2002) *Modern Applied Statistics with S*. Fourth edition. Springer.
Wand, M.P and Jones, M.C. (1995). *Kernel Smoothing*. London: Chapman & Hall/CRC.

magn.plot	<i>Transformed plot of the magnitudes distribution of an earthquakes catalog</i>
-----------	--

Description

Plots the logarithm of the cumulative frequency of exceedence vs. magnitude in an earthquake catalog.

Usage

```
magn.plot(catalog, ...)
```

Arguments

catalog	should be a eqcat object, or at least must contain a column with name magn1.
...	other arguments to be passed to plot()

Details

For each magnitude m_j , if N_j is the number of values of magn1 greater than m_j , the values of $\log(N_j)$ vs. m_j are plotted.

According to the Gutenberg-Richter law, this plot should be linear. If there is a linear behaviour only for values greater than a given m_0 , then m_0 is probably the magnitude threshold of the catalog.

Value

A new plot is printed (see details).

Author(s)

Marcello Chiodi.

Examples

```
## Not run:  
data(italycatalog)  
magn.plot(italycatalog)  
  
## End(Not run)
```

MLA.freq	<i>Display a pretty frequency table</i>
----------	---

Description

Display a pretty frequency table. It is only a wrapper to the function `table` but with a richer output, at least for numerical variables.

Usage

```
MLA.freq(x)
```

Arguments

`x` a numeric vector.

Details

The output gives the different kinds of frequencies and cumulated frequencies: single frequencies, cumulated and back cumulated (absolute and relatives).

Value

return a matrix with 7 columns: the modal distinct values of `x`, frequencies, relative frequencies, cumulated frequencies, cumulated relative frequencies, back cumulated frequencies and back cumulated relative frequencies.

Author(s)

Marcello Chiodi

Examples

```
x=trunc(runif(1000)*10)
MLA.freq(x)

data(italycatalog)
MLA.freq(italycatalog$magn1)
```

plot.etasclass *Plot method for etasclass objects*

Description

This is the main method to visualize graphically the output of an object of class etasclass.

By default the space-time region is the same used for the estimation of the ETAS model. Background, triggered and total space intensities are also plotted for a grid of values.

Usage

```
## S3 method for class 'etasclass'
plot(x, pdf=FALSE, file = "etasplot",
     ngrid=201, nclass=10, tfixed=0, flag.3D=FALSE, flag.log=FALSE, ...)
```

Arguments

x	an etaclass object.
pdf	If TRUE, then 2D plots are sent to a pdf file
file	name of the pdf file
ngrid	number of points for each direction (x, y) of a ngrid*ngrid grid where estimated intensities must be evaluated. Default value= 201.
nclass	number of class for each direction (x, y) of a grid of nclass*nclass cells where estimated intensities must be evaluated. Must divide ngrid-1. Default value= 10.
tfixed	If a positive value is given, then the triggered intensity at time tfixed is estimated and visualized.
flag.3D	If TRUE a 3D plot is also produced.
flag.log	If TRUE then a log scale is used to plot intensities.
...	other arguments.

Details

Different plots of the output of an object of class etasclass.

By default the space-time region is the same used for the estimation of the ETAS model. Background, triggered and total space intensities are also computed and plotted for a grid of values.

If a positive value is given for tfixed, then the triggered intensity at time tfixed is estimated and visualized. A typical use can be with tfixed a day after a big earthquake.

Starting with the package version 1.2.0 different kind of residual analysis are computed and visualized, separately for the space and time dimensions. (8 plot on three windows for the space and 2 plots on one window for the time)

For space dimension,

Space residuals are computed dividing the observed rectangular space area in a equally spaced grid of `nclass` intervals for each dimension, so to divide the observed space area in `nclass` x `nclass` rectangular cells. We obtain the classical comparison between observed and theoretical frequencies. All frequencies are related to the whole time interval (and thus theoretical frequencies are obtained integrating estimated intensities with respect to time).

Fifth graph (image plot)

We define `nclass` x `nclass` standardized residuals:

$$z_{\ell j} = \frac{n_{\ell j} - \hat{\nu}_{\ell j}}{\sqrt{\hat{\nu}_{\ell j}}} \quad (\ell = 1, 2, \dots, nclass; j = 1, 2, \dots, nclass)$$

For each cell ℓj we have observed ($n_{\ell j}$) and theoretical frequency ($\hat{\nu}_{\ell j}$).

Sixth graph (image plot)

We used a similar technique to compute residuals for the background seismicity only, to check if at least the estimation of the background component is appropriate. To this purpose the observed background frequencies (${}_b n_{\ell j}$) are now computed by the sum of the estimated weights `rho.weights` and the theoretical background frequency ${}_b \hat{\nu}_{\ell j}$ by the estimated marginal space background intensity in each cell.

From these quantities we obtain `nclass` x `nclass` standardized residuals for the background intensity only:

$${}_b z_{\ell j} = \frac{{}_b n_{\ell j} - {}_b \hat{\nu}_{\ell j}}{\sqrt{{}_b \hat{\nu}_{\ell j}}} \quad (\ell = 1, 2, \dots, nclass; j = 1, 2, \dots, nclass)$$

seventh plot: (space intensities (integrated over time))

A 3x2 plot: first column for observed vs.theoretical , second column for standardized residuals vs theoretical values. First row for total intensity, second row for background intensity, and third row for their difference, the triggered intensities

eight-th graph:

To check departure of the model for the time dimension, we first integrated the estimated intensity function with respect to the observed space region, so to obtain an estimated time process (a one dimensional ETAS model):

$$\hat{\lambda}(t) = \int \int_{\Omega(x,y)} \hat{\lambda}(x, y, t) dx dy$$

As known, a non-homogeneous time process can be transformed to a homogeneous one through the integral transformation:

$$\tau_i = \int_{t_0}^{t_i} \hat{\lambda}(t) dt$$

Then, a plot of τ_i versus i can give information about the departures of the models in the time dimension. In particular, this plot, together with a plot of the estimated time intensities, drawn on the same graphic window, can inform on the time at which departures are more evident

If `pdf=TRUE` all graphs are printed on a pdf file, as spcified by `file`; otherwise default screen device is used.

Value

This plot method computes, among others, `back.grid`, `trig.grid`, with coordinates `x.grid` and `y.grid` used to obtain image plots of background, triggered and total spatial estimated intensities (see [etasclass](#) to see the details of the mixed estimation method used).

<code>x.grid</code>	x grid values.
<code>y.grid</code>	y grid values.
<code>back.grid</code>	background intensity estimated on a <code>ngrid</code> x <code>ngrid</code> grid.
<code>trig.grid</code>	triggered intensities estimated on a grid of <code>ngrid</code> x <code>ngrid</code> points.
<code>tot.grid</code>	total intensities estimated on a grid of <code>ngrid</code> x <code>ngrid</code> points.
<code>back.grid</code>	background space intensity estimated for observed points.
<code>trig.grid</code>	triggered space intensities estimated for observed points.
<code>tot.grid</code>	total space intensities estimated for observed points.
<code>teo1</code>	matrix of <code>nclass</code> * <code>nclass</code> cells with theoretical total space intensities.
<code>teo2</code>	matrix of <code>nclass</code> * <code>nclass</code> cells with theoretical background space intensities.
<code>emp1</code>	matrix of <code>nclass</code> * <code>nclass</code> cells with empirical total space intensities.
<code>emp2</code>	matrix of <code>nclass</code> * <code>nclass</code> cells with empirical background space intensities.
<code>t.trasf</code>	vector of transformed times.

Note

In this first version the x-y space region, where the point process is defined, by default is a rectangle embedding the catalog values.

Author(s)

Marcello Chiodi, Giada Adelfio

See Also

[etasclass](#), [eqcat](#), [profile.etasclass](#)

Examples

```
## Not run:
data("italycatalog")
# load a sample catalog of the italian seismicity

class(italycatalog)<-"eqcat"

etas.flp<-etasclass(italycatalog,description="etas flp",magn.threshold=3.1,thinning=FALSE,flp=TRUE,
is.backconstant=FALSE,magn.threshold.back=3.5,sectoday=TRUE,
onlytime=FALSE,declustering=TRUE,epsmax=0.00001,
params.ind=c(1,1,1,1,1,1,1,1),k0=0.005,c=0.005,p=1.01,a=1.05,gamma=0.6,q=1.52,d=1.1,
compsqm=TRUE,usenlm=TRUE,ndclust=15)
```



```

# execution of etasclass for events with minimum magnitude of 3.1.
# The events with magnitude at least 3.5 are used to build a first approximation
# for the background intensity function
# (magn.threshold.back=3.5)

# plot method

plot(etas.flp)

## End(Not run)

```

```
plot.profile.etasclass
```

plot method for profile.etasclass objects (profile likelihood of ETAS model)

Description

plot method for profile.etasclass objects (profile likelihood of ETAS model). Plots a smooth interpolation of the profile likelihood of a parameter of an ETAS model, as output from profile.etasclass.

Usage

```
## S3 method for class 'profile.etasclass'
plot(x,prob=c(0.90,0.95,0.99),...)
```

Arguments

x	An object of the class profile.etasclass.
prob	A vector of coverage probability for the asymptotic confidence interval computed using $-2\log(LR)$. Default value prob=c(0.90,0.95,0.99).
...	other arguments.

Details

Plots a spline interpolation of the profile likelihood for a parameter of the ETAS model for earthquake seismicity, computed with profile.etasclass;

the order of parametrs is: (mu, k0, c, p, a, gamma, d, q).

A plot method is defined for profile.etasclass objects. A number of grid points nprofile of 7 (the default) usually is enough to have a good interpolation of the profile likelihood.

Value

Plots a profile likelihood (in the scale $-2\log(LR)$), and plots horizontal lines corresponding to the percentiles of a 1df chi-square variable of levels prob; the approximate confidence intervals corresponding to the levels prob are printed. Returns a list:

spline.profile The spline interpolation of the profile likelihood.
 conf The approximate confidence intervals corresponding to the levels prob.
 prob The prob values used.

Note

A odd number of grid points nprofile is advised, so that the central point is the unconstrained ML estimate for the profiled parameter, and the interpolation of the profile likelihood will have a better quality.

Author(s)

Marcello Chiodi, Giada Adelfio

See Also

[eqcat](#), [etasclass](#), [profile.etasclass](#)

Examples

```
## Not run:
## see example in profile.etasclass

## End(Not run)
```

print.etasclass *Print method for etasclass objects*

Description

Print method for an object of class etasclass.

Gives some information on the execution and gives estimates of the ETAS parameters.

Usage

```
## S3 method for class 'etasclass'
print(x,...)
```

Arguments

x an etaclass object.
 ... other arguments.

Details

Print brief information about an object of class etasclass. More output is obtained with summary.

Value

Displays parameters estimates and information on the execution of the etasclass estimation process. Displays also the exact call of the function that generated etasclass

Author(s)

Marcello Chiodi, Giada Adelfio

See Also

[etasclass](#), [eqcat](#), [profile.etasclass](#)

profile.etasclass *profile method for etasclass objects (ETAS model)*

Description

profile method for etasclass objects (ETAS model).

Usage

```
## S3 method for class 'etasclass'
profile(fitted,iprofile =4,
        nprofile =7,
        kprofile =3,
        profile.approx =FALSE,...)
```

Arguments

fitted	An object of the class etasclass.
iprofile	An integer in the range 1-8. Profile likelihood will be computed with respect to the parameter of index iprofile. The order of parametrs is: mu, k0, c, p, a, gamma, d, q.
nprofile	Number of values of params[iprofile] for which profile likelihood must be computed. Default value= 7.
kprofile	Maximum absolute standardized value for params[iprofile]. Profile likelihood will be computed in the standardized range [-kprofile, kprofile]. Default value= 3.
profile.approx	if TRUE, then a conditional-likelihood approach is used as a first value for each maximization step in profile likelihood computation. Default value= FALSE.
...	other arguments.

Details

Profile likelihood for the `iprofile`-th parameter of the ETAS model for earthquake seismicity, estimated with `etasclass`; the order of parameters is: $(\mu, k_0, c, p, a, \gamma, d, q)$.

A `plot` method is defined for `profile.etasclass` objects. A number of grid points `nprofile` of 7 (the default) usually is enough to have a good interpolation of the profile likelihood. The profile is computed using the final estimation of the background seismicity used to obtain the object `etas` of class `etasclass` and regardless to the method used. The computing time (for each of the `nprofile` values) is generally less than a single execution of `etasclass` without clustering, because only ML estimation is performed. Parameters not estimated in `etas` (with `params.ind[i]=FALSE`) will remain fixed do the value `params.fix[i]`.

To obtain profiles for different parameters, run `profile.etasclass` with different values of `iprofile`.

Value

Returns a list:

`params.vec` vector of values of the parameter `iprofile` used to evaluate the profile likelihood.

`logl.vec` vector of likelihoods corresponding to the values of `params.vec`

`plot` method is defined to represent profile likelihood (in scale $-2\log(LR)$), using a spline interpolation through grid points, with superimposition of approximate confidence intervals.

Note

A odd number of grid points `nprofile` is advised, so that the central point is the unconstrained ML estimate for the profiled parameter, and the interpolation of the profile likelihood will have a better quality.

Author(s)

Marcello Chiodi, Giada Adelfio

See Also

[eqcat](#), [etasclass](#), [plot.profile.etasclass](#)

Examples

```
## Not run: ##
data("italycatalog")
# load a sample catalog of italian seismicity

etas.flp=etasclass(italycatalog,
  magn.threshold = 3.0, magn.threshold.back = 3.5,
  k0 = 0.005, c = 0.005, p = 1.01, a = 1.05, gamma = 0.6, q = 1.52, d = 1.1,
  params.ind = c(TRUE, TRUE, TRUE, TRUE, TRUE, TRUE, TRUE, TRUE),
  declustering = TRUE, thinning = FALSE, flp = TRUE, ndeclust = 15,
  onlytime = FALSE, is.backconstant = FALSE,
  description = "etas flp",sectoday = TRUE, usenlm = TRUE, epsmax = 0.001)
```

```

# profile likelihood for the 5-th parameter (a), with plot:

prof.flp = profile(etas.flp, nprofile = 7, iprofile = 5)
plot(prof.flp)
Asymptotic confidence intervals:
  Coverage Lower Upper
1      0.90 1.393 1.624
2      0.95 1.381 1.635
3      0.99 1.346 1.659

## End(Not run)

```

simpson.coeff

Computes Simpson integration rule coefficients

Description

Computes Simpson integration rule coefficients.

Usage

```

simpson.coeff(n)
simpson.kD(n,k=2)

```

Arguments

n	number of points of the simpson formula a single dimension
k	number of dimensions

Details

simpson.coeff computes the coefficients of the standard Simpson rule (for unit spaced points), according to the sequence $(1+4+2+4+\dots+2+4+1)/3$ for each dimension. simpson.kD expand the formula over a grid of n^k points in k dimensions.

Value

a vector of n coefficients (for simpson.coeff), a k-dimensions array with a total of n^k elements for simpson.kD.

Author(s)

Marcello Chiodi

summary.etasclass *Summary method for etaclass objects*

Description

This is the main method to summarize the output of an object of class `etasclass`.

Gives some information on the execution and gives estimates of the ETAS parameters together with the standard errors.

Usage

```
## S3 method for class 'etasclass'  
summary(object,...)
```

Arguments

`object` an `etasclass` object to pass to `summary`.
`...` other arguments.

Details

Displays summary information about an object of class `etasclass`.

Value

Displays AIC values, parameters estimates and their standard errors, together with some information on the execution of the `etasclass` estimation process. Displays also the exact call of the function that generated `etasclass`

Author(s)

Marcello Chiodi, Giada Adelfio

See Also

[etasclass](#), [eqcat](#), [profile.etasclass](#)

Examples

```
## Not run:  
data("italycatalog")  
# load a sample catalog of the italian seismicity  
  
etas.flp=etasclass(italycatalog,  
magn.threshold = 3.0, magn.threshold.back = 3.5,  
k0 = 0.005, c = 0.005, p = 1.01, a = 1.05, gamma = 0.6, q = 1.52, d = 1.1,  
params.ind = c(TRUE, TRUE, TRUE, TRUE, TRUE, TRUE, TRUE, TRUE),
```

```

declustering = TRUE, thinning = FALSE, flp = TRUE, ndeclust = 15,
onlytime = FALSE, is.backconstant = FALSE,
description = "etas flp",sectoday = TRUE, usenlm = TRUE, epsmax = 0.001)
# execution of etasclass for events with minimum magnitude of 3.0.
# The events with magnitude at least 3.5 are used to build a first approximation
# for the background intensity function
# (magn.threshold.back=3.5)

```

```
# summary method for the etasclass object
```

```
summary(etas.flp)
```

```
Call:
```

```

etasclass(cat.orig = italycatalog, magn.threshold = 3, magn.threshold.back = 3.5,
  k0 = 0.005, c = 0.005, p = 1.01, a = 1.05, gamma = 0.6, d = 1.1,
  q = 1.52, params.ind = c(TRUE, TRUE, TRUE, TRUE, TRUE, TRUE,
    TRUE, TRUE), declustering = TRUE, thinning = FALSE, flp = TRUE,
  ndeclust = 15, onlytime = FALSE, is.backconstant = FALSE,
  description = "etas flp", sectoday = TRUE, usenlm = TRUE,
  epsmax = 0.001)

```

```

etas flp
Execution started:                2015-06-02 13:01:04
Elapsed time of execution (hours) 0.2473813
Number of observations            2158
Magnitude threshold              3
declustering                     TRUE
Number of declustering iterations 4
Kind of declustering             weighting
flp                              TRUE
sequence of AIC values for each iteration
49620.08 48458.86 48418.2 48415.17

```

```
-----
ETAS Parameters:
```

	Estimates	std.err.
mu	0.355850	0.011294
k0	0.008373	0.002053
c	0.009404	0.001795
p	1.121630	0.016271
a	1.509371	0.064077
gamma	0.857945	0.084688
d	1.915139	0.306384
q	1.836391	0.067067

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

time2date

Date time conversion tools

Description

Date time conversion tools, useful in connection with package etasFLP for earthquake description. Base date is Jan. 1st 1900.

Usage

```
time2date(t)
```

```
timecharunique2seq(timestring)
```

Arguments

t	seconds elapsed from 1900-1-1.
timestring	A time string.

Details

time2date converts sequential time in seconds into character string; timecharunique2seq converts character times of catalogs into sequential time (seconds elapsed from the base date): the input is a single string.

Value

time2date returns a character string; timecharunique2seq returns a list:

char	the input string.
sec	seconds elapsed from the base date.
day	days elapsed from the base date.

Author(s)

Marcello Chiodi

Examples

```
## Not run:
tchar="1960-11-06 11:09:35.000"
tsec =timecharunique2seq(tchar)[["sec"]]
time2date(tsec)

## End(Not run)
```

xy.grid	<i>Creates a 2-d grid</i>
---------	---------------------------

Description

Creates a 2-d grid.

Usage

```
xy.grid(rangex, rangey, nx, ny = nx)
```

Arguments

rangex	A length 2 numeric vector: the range of the x-variable.
rangey	A length 2 numeric vector: the range of the y-variable.
nx	The number of points of the grid in the x-direction.
ny	The number of points of the grid in the y-direction.

Value

A grid of the coordinates of $nx \times ny$ points on the x-y plane, expanded in a matrix of $nx \times ny$ rows and 2 columns: a row gives the (x,y) coordinates of a point.

Examples

```
xy.grid(c(3,7),c(11,17),nx=5,ny=4)
```

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