

Package ‘etasFLP’

July 23, 2025

Type Package

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

Version 2.2.2

Date 2023-09-14

Description Estimation of the components of an ETAS (Epidemic Type Aftershock Sequence) model for earthquake description. Non-parametric background seismicity can be estimated through FLP (Forward Likelihood Predictive). New version 2.0.0: covariates have been introduced to explain the effects of external factors on the induced seismicity; the parametrization has been changed; Chiodi, Adelfio (2017)<[doi:10.18637/jss.v076.i03](https://doi.org/10.18637/jss.v076.i03)>.

Imports fields,maps

License GPL (>= 2)

Depends R (>= 3.5.0), mapdata

Author Marcello Chiodi [aut, cre],
Giada Adelfio [aut]

Maintainer Marcello Chiodi <marcello.chiodi@unipa.it>

LazyData true

RoxygenNote 7.1.1

NeedsCompilation yes

Repository CRAN

Date/Publication 2023-09-14 14:00:02 UTC

Contents

etasFLP-package	2
b.guten	4
bwd.nrd	5
californiacatalog	6
catalog.withcov	7
compare.etasclass	8
daily.etasclass	9

eqcat	9
etas.starting	10
etasclass	13
italycatalog	22
kde2dnew.fortran	23
magn.plot	24
MLA.freq	25
plot.etasclass	26
plot.profile.etasclass	29
print.etasclass	31
profile.etasclass	32
simpson.coeff	34
summary.etasclass	35
time2date	38
timeupdate.etasclass	39
update.etasclass	40
xy.grid	41
Index	42

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

Description

New version 2.2.0. Covariates have been introduced to explain the effects of external factors on the induced seismicity. Since the parametrization is changed, the etasclass object created with the previous versions are not compatible with the one obtained with the current version. Estimation of the components of an ETAS (Epidemic Type Aftershock Sequence) 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 included; also plot, print, summary, profile methods are defined for main output (objects of class etasclass); update methods are now present.

Details

Package:	etasFLP
Type:	Package
Version:	2.2.2
Date:	2023-09-14
License:	GPL (>=2)
Imports: fields,maps	Depends: R (>= 3.5.0), mapdata
Suggests:	MASS

etasclass is the main function of the package etasFLP: strongly renewed from version 2.0. update.etasclass and timeupdate.etasclass two new different kind of updating existing etasclass objects. Very useful for large catalogues

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

Maintainer: Marcello Chiodi<marcello.chiodi@unipa.it>

References

- Adelfio G., Chiodi, M. (2009). Second-Order Diagnostics for Space-Time Point Processes with Application to Seismic Events. *Environmetrics*, **20**(8), 895-911. doi:10.1002/env.961.
- Adelfio, G., 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., 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* **29**(2), pp. 443-450. DOI: 10.1007/s00477-014-0873-8
- Adelfio G., Chiodi, M. (2015). FLP Estimation of Semi-Parametric Models for Space-Time Point Processes and Diagnostic Tools. *Spatial Statistics*, **14**(B), 119-132. doi:10.1016/j.spasta.2015.06.004.
- Adelfio G., Chiodi, M. (2020). Including covariates in a space-time point process with application to seismicity. *Statistical Methods and Applications*, doi:10.1007/s10260-020-00543-5.
- Adelfio G., Schoenberg, FP (2009). Point Process Diagnostics Based on Weighted Second- Order Statistics and Their Asymptotic Properties. *The Annals of the Institute of Statistical Mathematics*, **61**(4), 929-948. doi:10.1007/s10463-008-0177-1.
- Chiodi, M., Adelfio, G., (2011) Forward Likelihood-based predictive approach for space-time processes. *Environmetrics*, vol. **22** (6), pp. 749-757. DOI:10.1002/env.1121.
- Chiodi, M., Adelfio, G., (2017) Mixed Non-Parametric and Parametric Estimation Techniques in R Package etasFLP for Earthquakes' Description. *Journal of Statistical Software*, vol. **76** (3), pp. 1-29. DOI: 10.18637/jss.v076.i03
- 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). DOI:10.1007/s00024-010-0065-5.
- Nicolis, O., Chiodi, M. and Adelfio G. (2015) Windowed ETAS models with application to the Chilean seismic catalogs, *Spatial Statistics*, Volume **14**, Part B, November 2015, Pages 151-165, ISSN 2211-6753, <http://dx.doi.org/10.1016/j.spasta.2015.05.006>.
- 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. , 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). DOI:10.1198/016214502760046925.

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 likelihoedd 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

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

```
#####
```

californiacatalog	<i>Sample catalog of North California earthquakes</i>
-------------------	---

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)
```

catalog.withcov	<i>Small sample catalog of italian earthquakes with covariates</i>
-----------------	--

Description

A small sample catalog of italian earthquakes of magnitude at least 2.5 from May 2012 to May 2016 with extra information.

Usage

```
catalog.withcov
```

Format

a data matrix with 2,226 observations and 11 variables: Date, id_ev, time, lat, long, z, magn1, err_h_rev, min_distance_rev, rms_rev, nstaloc_rev .

Details

A small sample catalog of italian earthquakes of magnitude at least 2.5 from May 2012 to May 2016 with extra information. Date is the date, id_ev is an identifier of the events, time, lat, long, z, magn1 are time (days from 1900-01-01), latitude, longitude, depth, magnitude, err_h_rev is an estimate of hypocentral uncertainty, min_distance_rev is the distance from the nearest station, rms_rev is a measure of the quality of the location, nstaloc_rev is the number of stations that registered the event, distmin is the distance from the nearest fault

Source

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

References

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

Examples

```
data(catalog.withcov)
str(catalog.withcov)
```

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 estimated on the same catalog

Value

diffstd.params	Standardized comparison of the estimated parameters, included covariates.
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](#)

daily.etasclass	<i>Title daily.etasclass</i>
-----------------	------------------------------

Description

A daily estimation on a space grid is made

Usage

```
daily.etasclass(x, ngrid = 201, nclass = 20, tfixed = 0, flag.log = FALSE, ...)
```

Arguments

x	an etasclass object
ngrid	subdivisions of x and y axis for grid computation of intensities
nclass	number of class for horizontal and vertical axes of the output grid
tfixed	day of computation
flag.log	if log intensity must be used
...	other optional parameters

Value

a grid with daily theoretical intensities

eqcat	<i>Check earthquake catalog</i>
-------	---------------------------------

Description

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

Usage

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

Arguments

x	an earthquake catalog.
object	an eqcat object.
extended	if TRUE some extra summary functions are computed.
...	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. and the input object can be the cat output of eqcat

Value

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

cat	the input catalog is returned. If the check is ok, this is an eqcat class object.
ok	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. From version 2.0 you could use z as a covariate for the triggered component

Author(s)

Marcello Chiodi

See Also

[etasclass](#)

Examples

```
## Not run:
data(italycatalog)
f=eqcat(italycatalog)
print(f$ok)
summary(f$cat)
plot(f$cat)

## End(Not run)
```

etas.starting

Guess starting values of ETAS parameters (beta-version). Only from package version 1.2.0

Description

`etas.starting` is a simple function to give starting values of the 7 ETAS parameters for the function `etaclass`.

It gives only rough approximations, 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 starting values. In the present version user can give manually the output of this function in the input of `etaclass`. Otherwise, the function is called by `etaclass` at first steps, to supply initial values to start estimation.

Usage

```
etas.starting(cat.orig,
magn.threshold=2.5,
p.start=1,
gamma.start=0.5,
q.start=2,
betacov.start=.7,
longlat.to.km=TRUE,
sectoday=FALSE,
onlytime=FALSE
)
```

Arguments

<code>cat.orig</code>	An earthquake catalog, possibly an object of class <code>eqcat</code> , or however a <code>data.frame</code> with variables of names <code>time</code> , <code>lat</code> , <code>long</code> , <code>z</code> , <code>magn1</code> . No missing values are allowed.
<code>magn.threshold</code>	Threshold magnitude (only events with a magnitude at least <code>magn.threshold</code> will be used). Default value = 2.5.
<code>p.start</code>	Parameter 4 of the ETAS model; the exponent of the Omori law for temporal decay rate of aftershocks; see details. Default value = 1.0.
<code>gamma.start</code>	Parameter 5 (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 7 of the ETAS model; parameter related to the spatial influence of the mainshock; see details. Default value = 2.
<code>betacov.start</code>	coefficient of the covariate (as default the magnitude). Default value = 0.7.
<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.
<code>onlytime</code>	if TRUE then a time process is fitted to data, regardless to space location (in this case <code>is.backconstant</code> is set to TRUE and <code>declustering</code> , <code>flp</code> are set to FALSE). Default value = FALSE.

Details

It is a beta-version of a very crude method to give starting values for the seven 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 7 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`, `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 given the other starting values, 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>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 `ndclust`; 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 , 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	<i>Mixed estimation of an ETAS model (renewed in version 2.0)</i>
-----------	---

Description

etasclass is the main function of the package etasFLP.

etassclass objects of previous versions are not compatible with the current version

Performs the estimation of the components of the ETAS (Epidemic Type Aftershock Sequence) 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 (FLP) approach. For each event the probability of being a background event or a triggered one is estimated.

New in version 2.0.0: *Covariates have been introduced to explain the effects of external factors on the induced seismicity. Since the parametrization is changed, the etasclass object created with the previous versions are not compatible with the one obtained with the current version.*

New in version 2.2.0: *New algorithm for starting values. A new argument (n.iterweight) and an update method and a timeupdate option*

An ETAS with up to 7+ncov 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,
  time.update=FALSE,
  magn.threshold =2.5,
  magn.threshold.back=magn.threshold+2,
  tmax =max(cat.orig$time),
  long.range=range(cat.orig$long),
  lat.range=range(cat.orig$lat),
  ##### starting values for parameters
  mu =1,
  k0 =1,
  c =0.5,
  p =1.01,
  gamma =.5,
  d =1.,
  q =1.5,
  betacov          =0.7,
  ### indicators: if params.ind[i] i-th parameter will be estimated
  params.ind=replicate(7,TRUE),
#   params.lim=c(0,0,0,1.0,0,0,0),
  ### formula for covariates (magnitude should always be included):
  formula1          ="time~magnitude-1",
  offset            =0,
  hdef=c(1,1),
  w =replicate(nrow(cat.orig),1),
  hvarx =replicate(nrow(cat.orig),1),
  hvary =replicate(nrow(cat.orig),1),
  ### flags for the kind of declustering and smoothing:
  declustering      =TRUE,
  thinning          =FALSE,
  flp               =TRUE,
  m1                =NULL,
  ndeclust          =5,
  n.iterweight      =1,
  onlytime =FALSE,
  is.backconstant =FALSE,
  ##### end of main input arguments.
  ##### Control and secondary arguments:
  description = "",
  cat.back    =NULL,
  back.smooth =1.0,
  sectoday    =FALSE,
  longlat.to.km =TRUE,
#   fastML=FALSE, ##### not yet implemented
#   fast.eps=0.001, ##### not yet implemented
  usenlm =TRUE,
  method ="BFGS",
  compsqm =TRUE,

```

```
epsmax = 0.0001,
iterlim =50,
ntheta =36)
```

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.
time.update	Logical. It is TRUE if the execution is called by time.update to update to new time maximum. Default value = FALSE.
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.
tmax	Maximum value of time. Only observations before tmax will be used for estimation. Default value = max(cat.orig\$time).
long.range	Longitude range. Only observations with long in the range long.range will be used for estimation. Default value = range(cat.orig\$long).
lat.range	Latitude range. Only observations with lat in the range lat.range will be used for estimation. Default value = range(cat.orig\$lat).

Values for the 7 parameters of the ETAS model (starting values or fixed values according to params.ind):

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.
gamma	Parameter 5 (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 6 of the ETAS model; parameter related to the spatial influence of the mainshock; see details. Default value = 1.
q	Parameter 7 of the ETAS model; parameter related to the spatial influence of the mainshock; see details. Default value = 1.5.
betacov	Numerical array. Parameters of the covariates ETAS model (the parameters β_j); see details. Default value = 0.7. Parameters in betacov are not limited

End of model parameter input

<code>params.ind</code>	vector of 7 logical values: <code>params.ind[i] = TRUE</code> means that the i-th parameter must be estimated. <code>params.ind[i] = FALSE</code> means that the i-th parameter is fixed to its input value (the order of parameters is: <code>mu</code> , <code>k0</code> , <code>c</code> , <code>p</code> , <code>gamma</code> , <code>d</code> , <code>q</code>). Default value = <code>replicate(7, TRUE)</code> , that is, <code>etaclass</code> estimates all parameters.
<code>params.lim</code>	vector of 7 numerical values: <code>params.lim[i] = theta0</code> means that the i-th parameter must be greater than <code>theta0</code> (the default limits of parameters are: 0 for <code>mu</code> , <code>k0</code> , <code>c</code> , 1 for <code>p</code> , 0 for <code>gamma</code> , <code>d</code> , <code>q</code>). Default value = <code>replicate(7, TRUE)</code> , that is, <code>etaclass</code> estimates all parameters.
<code>formula1</code>	a character variable: Formula which defines the covariates acting on the induced seismicity. In classical <code>etas</code> model the covariate is the magnitude. The left side (dummy) element must be the time, which is a variable certainly present in the data set. The right part of the formula determines <code>ncov</code> the number of covariates. Default value = <code>"time~magnitude-1"</code> ; input <i>must</i> be a character value: it is converted in a formula inside the program
<code>offset</code>	An offset, for which no parameter will be estimated. Default value = 0

Flags for the kind of declustering and smoothing:

<code>hdef</code>	Starting values for the x,y bandwidths used in the kernel estimator of background seismicity. Default value = 1, 1.
<code>w</code>	Starting values for the weights used in the kernel estimator of background seismicity. The length must be equal to the number of events of the catalog after event selection (can be less than <code>nrow(cat.orig)</code>). Default value = <code>replicate(nrow(cat.orig), 1)</code> .
<code>hvarx</code>	Longitude bandwidths adjustment used in the kernel estimator of background seismicity. The length must be equal to the number of events of the catalog after event selection (can be less than <code>nrow(cat.orig)</code>). Default value = NULL
<code>hvary</code>	Longitude bandwidths adjustment used in the kernel estimator of background seismicity. The length must be equal to the number of events of the catalog after event selection (can be less than <code>nrow(cat.orig)</code>). Default value = NULL
<code>declustering</code>	if TRUE the catalog is iteratively declustered to optimally estimate the background intensity (through thinning, if <code>thinning=TRUE</code> , or through weighting if <code>thinning=FALSE</code>). Default value = TRUE.
<code>thinning</code>	if <code>thinning=TRUE</code> a background catalog is obtained sampling from the original catalog with probabilities estimated during the iterations. Default value = FALSE.
<code>flp</code>	if <code>flp=TRUE</code> then background seismicity is estimated through Forward Likelihood Predictive (see details). Otherwise the Silverman rule is used. Default value = TRUE.
<code>m1</code>	Used only if <code>flp=TRUE</code> . Indicates the range of points used for the FLP steps. See details. If missing it is set to <code>nrow(cat)/2</code> .
<code>ndeclust</code>	maximum number of iterations for the general declustering procedure. Default = 5.
<code>n.iterweight</code>	New in version 2.2. The weighting and the density computations will be alternated <code>n.iterweight</code> times after each maximum likelihood step: in many situations this improves the general convergence procedure. Default = 1.

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.

Other control parameters:

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 = FALSE.
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).
iterlim	maximum number of iterations in the maximum likelihood steps (used in nlm or optim). Default value = 100.
ntheta	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 sequence) model for the description of the seismicity of a space-time region. Background seismicity is estimated nonparametrically, while triggered seismicity is estimated by MLE.

From version 2.0 of package etasFLP covariates are allowed to improve the fitting of the triggered part, through the input formula1, which as a default values of "time ~ magnitude - 1", which corresponds to the previous version of package etasFLP, that is, magnitude as the only covariate which influence the average number of aftershocks.

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 trough the 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:

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

where $\eta_j = \sum_{j=1, ncov} \beta_j cov_{ij}$

parameters β_j are the elements of the array variable betacov

$f(x, y)$ 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.

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

k0 (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;

$\eta_j = \sum_{j=1, ncov} \beta_j cov_{ij}$ measures the efficiency of an event of a 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), and so a full 7+ncov parameters ETAS model will be estimated.

The seven parameters are internally ordered in this way: params = (mu, k0, c, p, 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 6+ncov parameters model can be fitted with gamma=0 and params.ind[5]=FALSE, so that input must be in this case: params.ind=c(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> or where the 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>).
<code>rho.weights</code>	Estimated probability for each event to be a background event (ρ).
<code>time.res</code>	rescaled time residuals (for time processes only).
<code>params.iter</code>	A matrix with estimates values at each iteration.
<code>sqm.iter</code>	A matrix with the estimates of the standard errors at each iteration.
<code>rho.weights.iter</code>	A matrix with the values of <code>rho.weights</code> at each iteration.
<code>l</code>	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 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; the function `etas.starting` gives rough first guess for initial values. If convergence problem are experienced, a useful strategy can be starting with an higher 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

- 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.
- Adelfio G, 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*, **29**(2), 443-450. doi:10.1007/s00477-014-0873-8.
- Adelfio G, Chiodi M (2015). FLP Estimation of Semi-Parametric Models for Space-Time Point Processes and Diagnostic Tools. *Spatial Statistics*, **14**(B), 119-132. doi:10.1016/j.spasta.2015.06.004.
- Adelfio G., Chiodi, M. (2020). Including covariates in a space-time point process with application to seismicity. *Statistical Methods and Applications*, doi:10.1007/s10260-020-00543-5.
- Chiodi, M. and Adelfio, G., (2011) Forward Likelihood-based predictive approach for space-time processes. *Environmetrics*, vol. **22** (6), pp. 749-757. DOI:10.1002/env.1121.
- Chiodi, M. and Adelfio, G., (2017) Mixed Non-Parametric and Parametric Estimation Techniques in R Package `etasFLP` for Earthquakes' Description. *Journal of Statistical Software*, vol. **76** (3), pp. 1-29. DOI: 10.18637/jss.v076.i03.
- 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). DOI:10.1198/016214502760046925.

See Also

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

Examples

```
## Not run:
data("italycatalog")
# load a sample catalog of the italian seismicity
esecov1<-etasclass(cat.orig = catalog.withcov, magn.threshold = 2.5, magn.threshold.back = 3.9,
mu = 0.3, k0 = 0.02, c = 0.015, p = 0.99, gamma = 0, d = 1,
q = 1.5, params.ind = c(TRUE, TRUE, TRUE, TRUE, FALSE, TRUE,
TRUE), formula1 = "time ~ magnitude- 1", declustering = TRUE,
thinning = FALSE, flp = TRUE, ndeclust = 15, onlytime = FALSE,
is.backconstant = FALSE, sectoday = FALSE, usenlm = TRUE,
compsqm = TRUE, epsmax = 1e-04, iterlim = 100, ntheta = 36)

# 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)
# The magnitude effect is given by the covariate magnitude
# in the formula "time ~ magnitude- 1"
# magnitude is the internal name for magn1-magn.threshold
# print method for the etasclass object

print(esecov1)

> print(esecov1)
Call:
etasclass(cat.orig = catalog.withcov, magn.threshold = 2.5, magn.threshold.back = 3.9,
mu = 0.3, k0 = 0.02, c = 0.015, p = 0.99, gamma = 0, d = 1,
q = 1.5, params.ind = c(TRUE, TRUE, TRUE, TRUE, FALSE, TRUE,
TRUE), formula1 = "time ~ magnitude- 1", declustering = TRUE,
thinning = FALSE, flp = TRUE, ndeclust = 15, onlytime = FALSE,
is.backconstant = FALSE, sectoday = FALSE, usenlm = TRUE,
compsqm = TRUE, epsmax = 1e-04, iterlim = 100, ntheta = 36)

Number of observations      2226
ETAS Parameters:
      mu      k0      c      p      gamma      d      q
0.667509 0.022393 0.014769 1.110059 0.000000 1.905461 1.947223
magnitude
0.740109
# summary method for more informative output etasclass object

summary(esecov1)
# plot results with maps of intensities and diagnostic tools
```

```

plot(esecov1)

## an application with 5 covariates
esecov5<-etasclass(cat.orig = catalog.withcov, magn.threshold = 2.5, magn.threshold.back = 3.9,
mu = 0.3, k0 = 0.02, c = 0.015, p = 0.99, gamma = 0, d = 1,
q = 1.5, params.ind = c(TRUE, TRUE, TRUE, TRUE, FALSE, TRUE, TRUE),
formula1 = "time ~ z + magnitude +nstaloc_rev +min_distance_rev+distmin- 1",
declustering = TRUE, thinning = FALSE, flp = TRUE, ndeclust = 15,
onlytime = FALSE, is.backconstant = FALSE, sectoday = FALSE,
usenlm = TRUE, compsqm = TRUE, epsmax = 1e-04, iterlim = 100,
ntheta = 36)

## print results, more out put with summary
print(esecov5)
Call:
etasclass(cat.orig = catalog.withcov, magn.threshold = 2.5, magn.threshold.back = 3.9,
mu = 0.3, k0 = 0.02, c = 0.015, p = 0.99, gamma = 0, d = 1,
q = 1.5, params.ind = c(TRUE, TRUE, TRUE, TRUE, FALSE, TRUE,
TRUE), formula1 = "time ~ z + magnitude +nstaloc_rev +min_distance_rev+distmin- 1",
declustering = TRUE, thinning = FALSE, flp = TRUE, ndeclust = 15,
onlytime = FALSE, is.backconstant = FALSE, sectoday = FALSE,
usenlm = TRUE, compsqm = TRUE, epsmax = 1e-04, iterlim = 100,
ntheta = 36)

Number of observations      2226
ETAS Parameters:
      mu      k0      c      p
0.705351 0.073070 0.019396 1.154186
      gamma      d      q      z
0.000000 1.942929 2.004915 -0.041256
magnitude nstaloc_rev min_distance_rev distmin
1.157698 -0.009010 -0.011020 -1.826717

## 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: <https://www.ingv.it/>.

Examples

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

kde2dnew.fortran	<i>A 2-d normal kernel estimator</i>
------------------	--------------------------------------

Description

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

Usage

```
kde2dnew.fortran(
#      parallel=FALSE,
      xkern,ykern,gx,gy,h,
      factor.xy=1,eps=0,w=replicate(length(xkern),1),
hvarx=replicate(length(xkern),1),hvary=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),
  hvarx=replicate(length(xkern),1),hvary=replicate(length(xkern),1)
)
```

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.

eps	enlargement factor for the region of interest.
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).
[]	
hvarx	Longitude bandwidths adjustment used in the kernel estimator of background seismicity. The length must be equal to the number of events of the catalog after event selection (can be less than nrow(cat.orig)). Default value = replicate(length(xkern),1)
hvary	Longitude bandwidths adjustment used in the kernel estimator of background seismicity. The length must be equal to the number of events of the catalog after event selection (can be less than nrow(cat.orig)).Default value = replicate(length(xkern),1)

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 eccedence vs. magnitude in an earthquake catalog.

Usage

```
magn.plot(catalog, main = "Transformed plot of magnitude frequencies", ...)
```

Arguments

catalog	should be a eqcat object, or at least must contain a column with name magn1.
main	Title to give to the plot
...	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

Display a pretty frequency table

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	<i>Plot method for etasclass objects</i>
----------------	--

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.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.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.

For space dimension, four plots are drawn with triggered, observed, total intensity, and total intensity with points.

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 plots on three windows for the space and 2 plots on one window for the time)

Then two plots are printed for space residuals for total and background intensities

Space residuals are computed dividing the observed rectangular space area in an 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 specified 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>tfixed</code>	the fixed time for which intensity is estimated and visualized.
<code>totfixed.grid</code>	total intensities estimated on a grid of <code>ngrid</code> x <code>ngrid</code> points at time <code>tfixed</code> .
<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

References

- Adelfio G, Chiodi M (2009). Second-Order Diagnostics for Space-Time Point Processes with Application to Seismic Events. *Environmetrics*, **20**(8), 895-911. doi:10.1002/env.961.
- Adelfio G, Chiodi M (2015). FLP Estimation of Semi-Parametric Models for Space-Time Point Processes and Diagnostic Tools. *Spatial Statistics*, **14**(B), 119-132. doi:10.1016/j.spasta.2015.06.004.
- Adelfio G, Schoenberg FP (2009). Point Process Diagnostics Based on Weighted Second- Order Statistics and Their Asymptotic Properties. *The Annals of the Institute of Statistical Mathematics*, **61**(4), 929-948. doi:10.1007/s10463-008-0177-1.
- Chiodi, M. and Adelfio, G., (2017) Mixed Non-Parametric and Parametric Estimation Techniques in R Package etasFLP for Earthquakes' Description. *Journal of Statistical Software*, vol. **76** (3), pp. 1-28. DOI: 10.18637/jss.v076.i03.

See Also

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

Examples

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

class(italycatalog)<-"eqcat"

# plot method

plot(\code{an etasclass object})

## 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), use.main = TRUE,...)
```

Arguments

<code>x</code>	An object of the class <code>profile.etasclass</code> .
<code>prob</code>	A vector of coverage probability for the asymptotic confidence interval computed using $-2\log(LR)$. Default value <code>prob=c(0.90,0.95,0.99)</code> .
<code>use.main</code>	Logical. If <code>use.main=TRUE</code> then a title is printed in the profile plot
<code>...</code>	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 parameters is: (μ , $k\theta$, c , p , a , γ , 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:

<code>spline.profile</code>	The spline interpolation of the profile likelihood.
<code>conf</code>	The approximate confidence intervals corresponding to the levels <code>prob</code> .
<code>prob</code>	The <code>prob</code> 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	<i>Print method for etasclass objects</i>
-----------------	---

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	<i>profile method for etasclass objects (ETAS model) (To be checked)</i>
-------------------	--

Description

profile method for etasclass objects (ETAS model).

Usage

```
## S3 method for class 'etasclass'
profile(fitted,iprofile =1,
        nprofile =7,
        kprofile =3,
        profile.approx =FALSE,...)
```

Arguments

fitted	An object of the class etasclass
.	
iprofile	An integer in the range 1-7. 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. In this version 2.0.0 profile only for etas parameters, not for covariates parameters. It will added future versions
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,k0,c,p,gamma,d,q and betacov.

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 adviced, 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, gamma = 0.6, q = 1.52, d = 1.1,
  params.ind = c(TRUE, TRUE, TRUE, TRUE, TRUE, TRUE, TRUE),
  formula1 = "time ~ magnitude- 1", 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)

## compute profile likelihood for the first parameter (mu)
system.time( prof.flp <- profile(etas.flp, nprofile = 7, iprofile = 1))
plot(prof.flp)
#### output:
Asymptotic confidence intervals:
  Coverage Lower Upper
1      0.90 0.335 0.376
```

```

2      0.95 0.334 0.378
3      0.99 0.329 0.385

```

```
## 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	<i>Summary method for etasclass objects</i>
-------------------	---

Description

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

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

More detailed output is available by inspecting `str(etasclass.object)`, and printing single objects.

Usage

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

Arguments

<code>object</code>	an <code>etasclass</code> object to pass to <code>summary</code> .
<code>full</code>	logical. New in version 2.2. If <code>TRUE</code> the full original call will be displayed together with some more output.
<code>...</code>	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:
# summary method for the etasclass object esecov1 and esecov5

(see examples in \code{\link{etasclass}})

## only with one covariate, the magnitude, classical ETAS model
> summary(esecov1)
Call:
etasclass(cat.orig = catalog.withcov, magn.threshold = 2.5, magn.threshold.back = 3.9,
  mu = 0.3, k0 = 0.02, c = 0.015, p = 0.99, gamma = 0, d = 1,
  q = 1.5, params.ind = c(TRUE, TRUE, TRUE, TRUE, FALSE, TRUE,
    TRUE), formula1 = "time ~ magnitude- 1", declustering = TRUE,
  thinning = FALSE, flp = TRUE, ndeclust = 15, onlytime = FALSE,
  is.backconstant = FALSE, sectoday = FALSE, usenlm = TRUE,
  compsqm = TRUE, epsmax = 1e-04, iterlim = 100, ntheta = 36)
```

```
Execution started:                2020-05-03 00:24:08
Elapsed time of execution (hours) 0.2294818
Number of observations            2226
Magnitude threshold               2.5
declustering                     TRUE
Number of declustering iterations 6
Kind of declustering              weighting
flp                              TRUE
sequence of AIC values for each iteration
44887.75 43348.46 43250.77 43249.77 43249.27 43249.19

final AIC value
44887.75 43348.46 43250.77 43249.77 43249.27 43249.19
```

```
-----
formula for covariates of the triggered components:
time ~ magnitude - 1
```

```
<environment: 0x55968d6fd660>
```

```
ETAS Parameters:
```

	Estimates	std.err.
mu	0.667509	0.022620
k0	0.022393	0.005781
c	0.014769	0.002708
p	1.110059	0.015709
gamma	0.000000	0.000000
d	1.905461	0.260360
q	1.947223	0.077627
magnitude	0.740109	0.092558

```
#### using covariates
> summary(esecov5)
Call:
```

```
etasclass(cat.orig = catalog.withcov, magn.threshold = 2.5, magn.threshold.back = 3.9,
  mu = 0.3, k0 = 0.02, c = 0.015, p = 0.99, gamma = 0, d = 1,
  q = 1.5, params.ind = c(TRUE, TRUE, TRUE, TRUE, FALSE, TRUE,
    TRUE), formula1 = "time ~ z + magnitude +nstaloc_rev +min_distance_rev+distmin- 1",
  declustering = TRUE, thinning = FALSE, flp = TRUE, ndeclust = 15,
  onlytime = FALSE, is.backconstant = FALSE, sectoday = FALSE,
  usenlm = TRUE, compsqm = TRUE, epsmax = 1e-04, iterlim = 100,
  ntheta = 36)
```

```
Execution started:          2020-05-03 12:22:31
Elapsed time of execution (hours)  0.4827933
Number of observations          2226
Magnitude threshold            2.5
declustering                   TRUE
Number of declustering iterations  3
Kind of declustering           weighting
flp                            TRUE
sequence of AIC values for each iteration
44693.04 42884.07 42706.16
```

```
final AIC value
44693.04 42884.07 42706.16
```

```
-----
formula for covariates of the triggered components:
time ~ z + magnitude + nstaloc_rev + min_distance_rev + distmin -
1
<environment: 0x55968d5ed118>
ETAS Parameters:
```

	Estimates	std.err.
mu	0.705351	0.022740
k0	0.073070	0.021194
c	0.019396	0.003435
p	1.154186	0.016874
gamma	0.000000	0.000000
d	1.942929	0.272434
q	2.004915	0.084784
z	-0.041256	0.005779
magnitude	1.157698	0.085360
nstaloc_rev	-0.009010	0.001817
min_distance_rev	-0.011020	0.002804
distmin	-1.826717	0.298649

```
-----
```

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

time2date	<i>Date time conversion tools</i>
-----------	-----------------------------------

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)
```

`timeupdate.etasclass` *timeupdate.etasclass*

Description

New in version 2.2. A time updating of an etasclass objects: a very experimental version that can be used only on etasclass objects obtained from etasflp versions 2.2 or newer.

Usage

```
timeupdate.etasclass(object, params.estimation = FALSE, ...)
```

Arguments

<code>object</code>	an etasclass object obtained from etasFLP versions 2.2 or newer that will be updated for a new time window with new events.
<code>params.estimation</code>	logical. if TRUE parameters will be estimated again even if quickly, with few optimizations steps. Elsewhere ETAS estimates of input object will be maintained
<code>...</code>	optional arguments that will override the corresponding arguments in object, possibly including a new catalog input or a new tmax

Details

It is a beta version. A new ETAS model is fitted to a previous object of class etasclass with a new catalog which must be a catalog which extends the previous one on a wider time window, that is a catalog with new observations.

As a default a new quick execution is made, with one quick iteration for parameter updating and an iteration for background density estimation.

Value

a new etasclass object

See Also

[update.etasclass](#)

update.etasclass	<i>update.etasclass</i>
------------------	-------------------------

Description

New in version 2.2. A method update for etasclass objects: a very experimental version that can be used only on etasclass objects obtained from etasflp versions 2.2 or newer.

Usage

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

Arguments

object	an etasclass object obtained from etasflp versions 2.2 or newer that will be updated.
...	optional arguments that will override the corresponding arguments in object

Details

It is a beta version. The catalog must be the same, and options in "..." must leave unchanged the number of observations used for estimation. Arguments given in "..." will override arguments already present in object. Not all arguments are suitable for updating: among them formula and params.ind should not be included in "..." list (to update such parameters it is better to assign them to a variable and then pass the variable name) . A new etasclass execution will start, using as arguments values of input object, eventually integrated with the list in "...". Typically a first execution can be given with low values of iterlim, ndeclust, ntheta and high values of epsmax (e.g. iterlim=5, ndeclust=1, ntheta=24, epsmax=0.01), to obtain good starting values for parameters and for weights. Then an update can be run with better values such as iterlim=50, ndeclust=10, ntheta=60, epsmax=0.0001.

Value

un updated etasclass object

See Also

[timeupdate.etasclass](#)

`xy.grid`

Creates a 2-d grid

Description

Creates a 2-d grid.

Usage

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

Arguments

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

Index

- * **ETAS**
 - etas.starting, 10
 - etasclass, 13
 - etasFLP-package, 2
 - plot.etasclass, 26
 - plot.profile.etasclass, 29
 - print.etasclass, 31
 - profile.etasclass, 32
 - summary.etasclass, 35
- * **FLP**
 - etasFLP-package, 2
- * **Gutenberg-Richter**
 - magn.plot, 24
- * **Gutenberg**
 - b.guten, 4
- * **MLE**
 - etasFLP-package, 2
- * **PointProcess**
 - etasFLP-package, 2
- * **Richter**
 - b.guten, 4
- * **bandwidth**
 - bwd.nrd, 5
- * **catalog**
 - compare.etasclass, 8
 - eqcat, 9
- * **covariates**
 - etasclass, 13
- * **datasets**
 - californiacatalog, 6
 - catalog.withcov, 7
 - italycatalog, 22
- * **date**
 - time2date, 38
- * **earthquakes**
 - etasFLP-package, 2
- * **earthquake**
 - b.guten, 4
 - californiacatalog, 6
 - catalog.withcov, 7
 - compare.etasclass, 8
 - eqcat, 9
 - etas.starting, 10
 - etasclass, 13
 - italycatalog, 22
 - plot.etasclass, 26
 - plot.profile.etasclass, 29
 - print.etasclass, 31
 - profile.etasclass, 32
 - summary.etasclass, 35
- * **etasclass**
 - compare.etasclass, 8
- * **flp**
 - etasclass, 13
- * **kernel**
 - bwd.nrd, 5
 - etasclass, 13
 - kde2dnew.fortran, 23
- * **likelihood**
 - etas.starting, 10
 - plot.profile.etasclass, 29
 - profile.etasclass, 32
- * **magnitude**
 - b.guten, 4
 - magn.plot, 24
- * **package**
 - etasFLP-package, 2
- * **plot**
 - plot.etasclass, 26
- * **print**
 - print.etasclass, 31
- * **profile**
 - plot.profile.etasclass, 29
 - profile.etasclass, 32
- * **quadrature**
 - simpson.coeff, 34
- * **simpson**
 - simpson.coeff, 34

*** summary**

summary.etasclass, 35

b.guten, 4

bw.nrd, 6

bwd.nrd, 5

californiacatalog, 6

catalog.withcov, 7

compare.etasclass, 8

daily.etasclass, 9

eqcat, 9, 21, 29–31, 33, 35

etas.starting, 10, 21

etasclass, 8, 10, 13, 13, 28–31, 33, 35

etasFLP (etasFLP-package), 2

etasFLP-package, 2

italycatalog, 22

kde2d.integral (kde2dnew.fortran), 23

kde2dnew.fortran, 23

magn.plot, 5, 24

MLA.freq, 25

plot.eqcat (eqcat), 9

plot.etasclass, 21, 26

plot.profile.etasclass, 29, 33

print.etasclass, 21, 31

profile.etasclass, 19, 21, 29–31, 32, 35

simpson.coeff, 34

simpson.kD (simpson.coeff), 34

summary.eqcat (eqcat), 9

summary.etasclass, 21, 35

time2date, 38

timecharunique2seq (time2date), 38

timeupdate.etasclass, 39, 40

update.etasclass, 39, 40

xy.grid, 41