

Package ‘INLABMA’

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Title Bayesian Model Averaging with INLA

Author

Virgilio Gómez-Rubio <virgilio.gomez@uclm.es>, Roger Bivand <Roger.Bivand@nhh.no>

Maintainer Virgilio Gómez-Rubio <virgilio.gomez@uclm.es>

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Imports Matrix, spdep, methods

Suggests INLA

Description Fit Spatial Econometrics models using Bayesian model averaging on models fitted with INLA. The INLA package can be obtained from <<https://www.r-inla.org>>.

License GPL (>= 2)

Additional_repositories <https://inla.r-inla-download.org/R/stable/>

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BMArho	<i>Compute BMA of fitted.values from a list of INLA objects</i>
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Description

This functions performs a weighted average of the component fitted.values from a list of INLA objects.

Usage

```
BMArho(models, rho, logrhoprior = rep(1, length(rho)))
```

Arguments

models	List of INLA models fitted for different values of rho
rho	Vector fo values of rho used to compute the list in models.
logrhoprior	Log-prior density for each value of rho.

Details

The different fitted.values are weighted using the values of the marginal likelihood of the fitted models and the prior of parameter rho. rho is a parameter that is fixed when computing models and that have a log-prior density defined in pogrhoprior.

Value

Vector of averaged fitted values.

Author(s)

Virgilio Gómez-Rubio <virgilio.gomez@uclm.es>

References

Roger S. Bivand, Virgilio Gómez-Rubio, Håvard Rue (2014). Approximate Bayesian inference for spatial econometrics models. *Spatial Statistics*, Volume 9, 146-165.

Roger S. Bivand, Virgilio Gómez-Rubio, Håvard Rue (2015). Spatial Data Analysis with R-INLA with Some Extensions. *Journal of Statistical Software*, 63(20), 1-31. URL <http://www.jstatsoft.org/v63/i20/>.

See Also

[INLABMA](#)

fitmarg*Fit posterior marginal distributions to points*

Description

Compute (and re-scale, if necessary) the marginal from a set of points x and values of log-likelihood $\log y$ and log-prior density $\log p$.

Usage

```
fitmarg(x, logy, logp = 0, usenormal = FALSE)
```

Arguments

x	Values of the random variable.
$\log y$	Log-likelihood.
$\log p$	Log-prior density.
<code>usenormal</code>	Whether use a Normal distribution for the fitted marginal.

Details

Fits a marginal at a set of points x from their log-likelihood and log-prior. The fitted marginal is re-scaled to integrate one if necessary. If `usenormal=TRUE` then the fitted marginal is supposed to be Normal, which is computed using the posterior mean and standard deviation of x .

Value

A function with the fitted marginal is returned.

Author(s)

Virgilio Gómez-Rubio <virgilio.gomez@uclm.es>

See Also

[fitmargBMA](#), [fitmargBMA2](#), [mysplinefun](#)

fitmargBMA

Compute marginals using Bayesian Model Averaging

Description

fitmargBMA takes a list of marginal distributions and weights (presumably, based on some marginal likelihoods) and computes a final distribution by weighting.

fitmargBMA2 takes a list of INLA models and computes Bayesian Model Averaging on some of their components.

fitmatrixBMA performs averaging on a list of matrices.

fitlistBMA performs averaging of elements in lists.

Usage

```
fitmargBMA(margs, ws, len = 100)
fitmargBMA2(models, ws, item)
fitmatrixBMA(models, ws, item)
fitlistBMA(models, ws, item)
```

Arguments

margs	List of 2-column matrices with the values of the (marginal) distributions.
models	List of INLA models to be averaged.
ws	Vector of weights. They do not need to sum up to one.
len	Length of the x-vector to compute the weighted distribution.
item	Name of the elements of an INLA object to be used in the Model Averaging.

Details

For fitmargBMA, distributions provided are averaging according to the weights provided. A new probability distribution is obtained.

fitmargBMA2 uses a list of INLA models to compute Model Averaging on some of their components (for example, the fitted values).

fitmatrixBMA performs averaging on a list of matrices.

fitlistBMA performs averaging of a list of a list of matrices.

Value

fitmargBMA returns a 2-column matrix with the weighted marginal distribution.

fitmargBMA2 returns a list of weighted components.

fitmatrixBMA returns a matrix.

fitlistBMA returns a list.

Author(s)

Virgilio Gómez-Rubio <virgilio.gomez@uclm.es>

INLABMA

Perform complete Bayesian Model Averaging on some Spatial Econometrics models

Description

This function performs Bayesian Model Averaging on a list of different Spatial Econometrics models. These models have been computed under different values of the spatial autocorrelation parameter ρ .

Usage

```
INLABMA(models, rho, logrhoprior = rep(1, length(rho)), impacts = FALSE,  
        usenormal = FALSE)
```

Arguments

<code>models</code>	List of INLA models, computed for different values of ρ .
<code>rho</code>	A vector with the values of ρ used to compute models.
<code>logrhoprior</code>	Vector with the values of the log-prior density of ρ .
<code>impacts</code>	Logical. Whether impacts should be computed.
<code>usenormal</code>	Logical. Whether the posterior marginal of ρ is assumed to be Gaussian.

Details

This functions performs BMA on most of the components of an INLA model using the marginal likelihoods of the models and the provided log-prior density of ρ .

Value

A list with the averaged components. Another component called `rho` is added, with its posterior marginal and some other summary information.

Author(s)

Virgilio Gómez-Rubio <virgilio.gomez@uclm.es>

References

Roger S. Bivand, Virgilio Gómez-Rubio, Håvard Rue (2014). Approximate Bayesian inference for spatial econometrics models. *Spatial Statistics*, Volume 9, 146-165.

Roger S. Bivand, Virgilio Gómez-Rubio, Håvard Rue (2015). Spatial Data Analysis with R-INLA with Some Extensions. *Journal of Statistical Software*, 63(20), 1-31. URL <http://www.jstatsoft.org/v63/i20/>.

See Also

[sem.inla](#), [slm.inla](#), [sdm.inla](#)

INLAMH

Perform INLA with MCMC.

Description

This function implements the Metropolis-Hastings algorithm using repeated calls to R-INLA to find conditional model on the current state of the MCMC simulations.

Usage

```
INLAMH(d, fit.inla, b.init, rq, dq, prior, n.sim = 200, n.burnin = 100,
       n.thin = 1, n.errors = 20, verbose = FALSE)
```

Arguments

<code>d</code>	Data.frame with the data used to fit the model with R-INLA.
<code>fit.inla</code>	A function used to fit the model with R-INLA. It should take at least two arguments: a data.frame (first) and an object with the actual value of the sampled parameters. This function must return a vector of two components: <code>model.sim</code> (an 'inla' object with the fitted model) and 'mlik' (the marginal likelihood as returned by INLA in <code>model.sim\$mlik</code>).
<code>b.init</code>	Initial values of the model parameters for the Metropolis-Hastings algorithm.
<code>rq</code>	Sampling from the proposal distribution. It must take one argument: the current state of the Markov chain.
<code>dq</code>	Density of the proposal distribution. It takes two arguments: current state and proposed new state.
<code>prior</code>	Prior distribution of the model parameters.
<code>n.sim</code>	Total of simulations to be done.
<code>n.burnin</code>	Number of burn-in simulation (thinning is ignored here).
<code>n.thin</code>	Thinning to be applied to the simulations after burn-in.
<code>n.errors</code>	This is the number of errors allowed when calling <code>inla()</code> .
<code>verbose</code>	Whether to show some running information or not (default to FALSE).

Details

This function implements the Metropolis-Hastings algorithm using INLA (i.e., INLA within MCMC) at every step. In practice, only a few of the model parameters are sampled in the MCMC steps and the posterior marginal of the remainder of parameters is obtained by Bayesian model averaging of the conditional marginals returned by R-INLA at each step of the Metropolis-Hastings algorithm.

Value

A list with three components:

<code>acc.sim</code>	A vector of logical values (of length 'n.sim') showing whether a given proposal has been accepted or not. This is useful to compute the acceptance rate.
<code>model.sim</code>	A list with the models fitted, as returned by <code>fit.inla()</code> .
<code>b.sim</code>	List of all sampled values of the models parameters. It is a list because the sampled values can be vectors.

Author(s)

Virgilio Gómez-Rubio.

References

Virgilio Gómez-Rubio and Haavard Rue (2017). Markov Chain Monte Carlo with the Integrated Nested Laplace Approximation. [doi:10.1007/s112220179778y](https://doi.org/10.1007/s112220179778y).

<code>leroux.inla</code>	<i>Fit Leroux et al's spatial model.</i>
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Description

This function fits the model by Leroux et al. for a given value of the parameter `lambda`, i.e., the mixture parameter that appears in the variance..

Usage

```
leroux.inla(formula, d, W, lambda, improve = TRUE, fhyper = NULL, ...)
```

Arguments

<code>formula</code>	Formula of the fixed effects.
<code>d</code>	A data.frame with the data to be used.
<code>W</code>	Adjacency matrix.
<code>lambda</code>	Parameter used in the mixture of the two precision matrices.
<code>improve</code>	Logical. Whether to improve the fitted models to obtain better estimates of the marginal likelihoods.
<code>fhyper</code>	Extra arguments passed to the definition of the hyperparameters.
<code>...</code>	Extra arguments passed to function <code>inla</code> .

Details

This function fits the model proposed by Leroux et al. (1999) for a given value of parameter `lambda`. This parameter controls the mixture between a diagonal precision (`lambda=1`) and an intrinsic CAR precision (`lambda=0`).

The marginal log-likelihood is corrected to add half the log-determinant of the precision matrix.

Value

An INLA object.

Author(s)

Virgilio Gómez-Rubio <virgilio.gomez@uclm.es>

References

- Leroux B, Lei X, Breslow N (1999). Estimation of Disease Rates in Small Areas: A New Mixed Model for Spatial Dependence. In M Halloran, D Berry (eds.), Statistical Models in Epidemiology, the Environment and Clinical Trials, pp. 135-178. Springer-Verlag, New York.
- Roger S. Bivand, Virgilio Gómez-Rubio, Håvard Rue (2014). Approximate Bayesian inference for spatial econometrics models. Spatial Statistics, Volume 9, 146-165.
- Roger S. Bivand, Virgilio Gómez-Rubio, Håvard Rue (2015). Spatial Data Analysis with R-INLA with Some Extensions. Journal of Statistical Software, 63(20), 1-31. URL <http://www.jstatsoft.org/v63/i20/>.

See Also

[sem.inla](#), [slm.inla](#), [sdm.inla](#)

logprrho

Log-prior density for the spatial autocorrelation parameter rho

Description

Compute log-prior density for rho

Usage

```
logprrho(rho)
```

Arguments

rho The value to compute the log-density.

Details

This function computes the log-density of the prior for rho according to $\text{logit}(\rho) \sim N(0, \text{prec}=.1)$. This is one of the default priors in **R-INLA** for spatial autocorrelation parameters.

Value

Numerical.

Author(s)

Virgilio Gómez-Rubio <virgilio.gomez@uclm.es>

Examples

```
rrho<-seq(.01, .99, length.out=100)
plot(rrho, exp(logprrho(rrho)))
```

mysplinefun	<i>Compute spline function</i>
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Description

This function is similar to `splinefun` but it returns 0 outside the range of `x`.

Usage

```
mysplinefun(x, y = NULL, method = c("fmm", "periodic", "natural", "monoH.FC")[1],
  ties = mean)
```

Arguments

<code>x</code>	<code>x</code> -values to use in the interpolation.
<code>y</code>	<code>y</code> -values to use in the interpolation (optional).
<code>method</code>	Method used to compute the spline. See splinefun for details.
<code>ties</code>	Handling of tied ' <code>x</code> ' values. See splinefun for details.

Details

This function calls [splinefun](#) and returns a function with the fitted spline. The main difference is that this new function returns 0 outside the range of 0.

Value

Returns a function with `x` and `deriv` arguments. See [splinefun](#) for details.

Author(s)

Virgilio Gómez-Rubio <virgilio.gomez@uclm.es>

See Also

[splinefun](#)

recompute.impacts	<i>Recompute the impact summaries from the marginals</i>
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Description

This functions recomputes the impacts summaries using the (approximated) marginals rather than by weighting on the different summaries.

Usage

```
recompute.impacts(obj, impacts = c("total", "direct", "indirect"))
```

Arguments

obj	Object with a resulting model obtained by Bayesian Model Averaging with INLABMA.
impacts	Types of impacts to recompute.

Details

This function uses the impacts marginals to compute some summary statistics. By default, the summary of the impacts is obtained by weighting the different summaries used in Bayesian Model Averaging with function INLABMA.

Value

Original object with the updated summary statistics of the impacts.

Author(s)

Virgilio Gómez-Rubio <virgilio.gomez@uclm.es>

References

Bivand et al. (2013)

See Also

[INLABMA](#)

rescalemarg	<i>Re-scale marginal distribution to compute the distribution of $w \cdot x$</i>
-------------	---

Description

This function takes a marginal distribution (represented by a 2-column matrix) and computes the marginal distribution of $w \cdot x$.

Usage

```
rescalemarg(xx, w)
```

Arguments

xx	2-column matrix with x and y-values.
w	Weight to re-scale the y-values.

Details

This function simply re-scales

Value

A 2-column matrix with the new values of $w \cdot x$ and their associated probability densities. This is also an object of classes `inla.marginal`.

Author(s)

Virgilio Gómez-Rubio <virgilio.gomez@uclm.es>

References

INLA

See Also

`inla.tmarginal`

Examples

```
if(requireNamespace("INLA", quietly = TRUE)) {
  require(INLA)
  x<-seq(-3,3, by=.01)
  xx<-cbind(x, dnorm(x))

  xx2<-rescalemarg(xx, 3)

  plot(xx, type="l", xlim=c(-9,9))
  lines(xx2, col="red")
}
```

sem.inla

*Fit spatial econometrics models with INLA***Description**

These functions fit some spatial econometrics models for a given value of ρ (the spatial autocorrelation parameter). `sem.inla` fits a spatial error model, `slm` fits a spatial lag model and `sdm.inla` fits a spatial Durbin model.

Usage

```
sem.inla(formula, d, W, rho, improve = TRUE, impacts = FALSE, fhyper = NULL,
         probit = FALSE, ...)
slm.inla(formula, d, W, rho, mmatrix = NULL, improve = TRUE, impacts = FALSE,
         fhyper = NULL, probit = FALSE, ...)
sdm.inla(formula, d, W, rho, mmatrix = NULL, intercept = TRUE, impacts = FALSE,
         improve = TRUE, fhyper = NULL, probit = FALSE, ...)
sac.inla(formula, d, W.rho, W.lambda, rho, lambda, mmatrix = NULL,
         improve = TRUE, impacts = FALSE, fhyper = NULL, probit = FALSE, ...)
```

Arguments

<code>formula</code>	Formula with the response variable, the fixed effects and, possibly, other non-linear effects.
<code>d</code>	Data.frame with the data.
<code>W</code>	Adjacency matrix.
<code>rho</code>	Value of the spatial autocorrelation parameter. For the SAC model, spatial autocorrelation term on the response.
<code>W.rho</code>	For the SAC model, adjacency matrix associated to the autocorrelation on the response.
<code>W.lambda</code>	For the SAC model, adjacency matrix associated to the autocorrelation on the error term.
<code>lambda</code>	For the SAC model, spatial autocorrelation of the error term.
<code>mmatrix</code>	Design matrix of fixed effects.
<code>intercept</code>	Logical. Whether an intercept has been included in the model.
<code>improve</code>	Logical. Whether improve model fitting (this may require more computing time).
<code>impacts</code>	Logical. Whether impacts are computed.
<code>fhyper</code>	Options to be passed to the definition of the hyper-parameters in the spatial effects.
<code>probit</code>	Logical. Whether a probit model is used. Note this is only used when computing the impacts and that argument family must be set accordingly.
<code>...</code>	Other arguments passed to function <code>inla</code> .

Details

These functions fit a spatial econometrics model with a fixed value of the spatial autocorrelation parameter ρ .

In addition, the marginal -log-likelihood is corrected to account for the variance-covariance matrix of the error term or random effects.

Value

An inla object.

Author(s)

Virgilio Gómez-Rubio <virgilio.gomez@uclm.es>

References

Roger S. Bivand, Virgilio Gómez-Rubio, Håvard Rue (2014). Approximate Bayesian inference for spatial econometrics models. *Spatial Statistics*, Volume 9, 146-165.

Roger S. Bivand, Virgilio Gómez-Rubio, Håvard Rue (2015). Spatial Data Analysis with R-INLA with Some Extensions. *Journal of Statistical Software*, 63(20), 1-31. URL <http://www.jstatsoft.org/v63/i20/>.

Virgilio Gómez-Rubio and Francisco-Palmí Perales (2016). Spatial Models with the Integrated Nested Laplace Approximation within Markov Chain Monte Carlo. Submitted.

See Also

[leroux.inla](#)

Examples

```
## Not run:

if(requireNamespace("INLA", quietly = TRUE)) {
  require(INLA)
  require(spdep)

  data(columbus)

  lw <- nb2listw(col.gal.nb, style="W")

  #Maximum Likelihood (ML) estimation
  colsemml <- errorsarlm(CRIME ~ INC + HOVAL, data=columbus, lw, method="eigen",
    quiet=FALSE)
  colslmml <- lagsarlm(CRIME ~ INC + HOVAL, data=columbus, lw, method="eigen",
    type="lag", quiet=FALSE)
  colsdmml <- lagsarlm(CRIME ~ INC + HOVAL, data=columbus, lw, method="eigen",
    type="mixed", quiet=FALSE)

  #Define grid on rho
  rrho<-seq(-1, .95, length.out=40)
```

```

#Adjacency matrix
W <- as(as_dgRMatrix_listw(nb2listw(col.gal.nb)), "CsparseMatrix")
#Index for spatial random effects
columbus$idx<-1:nrow(columbus)

#Formula
form<- CRIME ~ INC + HOVAL

zero.variance = list(prec=list(initial = 25, fixed=TRUE))

seminla<-mclapply(rrho, function(rho){
  sem.inla(form, d=columbus, W=W, rho=rho,
    family = "gaussian", impacts=FALSE,
    control.family = list(hyper = zero.variance),
    control.predictor=list(compute=TRUE),
    control.compute=list(dic=TRUE, cpo=TRUE),
    control.inla=list(print.joint.hyper=TRUE),
    #tolerance=1e-20, h=1e-6),
    verbose=FALSE
  )
})

slminla<-mclapply(rrho, function(rho){
  slm.inla(form, d=columbus, W=W, rho=rho,
    family = "gaussian", impacts=FALSE,
    control.family = list(hyper = zero.variance),
    control.predictor=list(compute=TRUE),
    control.compute=list(dic=TRUE, cpo=TRUE),
    control.inla=list(print.joint.hyper=TRUE),
    #tolerance=1e-20, h=1e-6),
    verbose=FALSE
  )
})

sdminla<-mclapply(rrho, function(rho){
  sdm.inla(form, d=columbus, W=W, rho=rho,
    family = "gaussian", impacts=FALSE,
    control.family = list(hyper = zero.variance),
    control.predictor=list(compute=TRUE),
    control.compute=list(dic=TRUE, cpo=TRUE),
    control.inla=list(print.joint.hyper=TRUE),
    #tolerance=1e-20, h=1e-6),
    verbose=FALSE
  )
})

```

```

}))

#BMA using a uniform prior (in the log-scale) and using a Gaussian
#approximation to the marginal
sembma<-INLABMA(seminla, rrho, 0, usenormal=TRUE)
slmbma<-INLABMA(slminla, rrho, 0, usenormal=TRUE)
sdmbma<-INLABMA(sdminla, rrho, 0, usenormal=TRUE)

#Display results
plot(sembma$rho$marginal, type="l", ylim=c(0,5))
lines(slmbma$rho$marginal, lty=2)
lines(sdmbma$rho$marginal, lty=3)
#Add ML estimates
abline(v=colsemml$lambda, col="red")
abline(v=colslmml$rho, col="red", lty=2)
abline(v=colsdmml$rho, col="red", lty=3)
#Legend
legend(-1,5, c("SEM", "SLM", "SDM"), lty=1:3)
}

## End(Not run)

```

trIrhoWinv

*Compute trace of $(I-\rho*W)^{-1}$ matrix*

Description

This function computes (or estimates) the trace of matrix $(I-\rho*W)^{-1}$, which is often needed when computing impacts in some spatial econometrics models.

Usage

```
trIrhoWinv(W, rho, offset = 0, order = 20, direct = TRUE, Df = Matrix::Diagonal(nrow(W)))
```

Arguments

W	Adjacency matrix. Usually, it is row-standardised.
rho	Value of spatial autocorrelation parameter rho.
offset	Number of times $(I-\rho*W)^{-1}$ is multiplied by W (for sdm model).
order	Order of Taylor expansion used in the approximation of the trace.
direct	Use direct method, i.e., matrix multiplication, etc.
Df	Diagonal matrix used to compute the impacts in the Probit model only used if direct=TRUE.

Details

This function computes the trace of $(I - \rho * W)^{-1}$, which is later used to compute the impacts. This is an internal function.

Value

Numerical value.

Author(s)

Virgilio Gómez-Rubio <virgilio.gomez@uclm.es>

References

LeSage and Page (2008) Bivand et al. (2013)

See Also

[sem.inla](#), [slm.inla](#), [sdm.inla](#)

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