

# Package: DSSP (via r-universe)

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**Title** Implementation of the Direct Sampling Spatial Prior

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**Description** Draw samples from the direct sampling spatial prior model as described in G. White, D. Sun, P. Speckman (2019) <[arXiv:1906.05575](https://arxiv.org/abs/1906.05575)>. The basic model assumes a Gaussian likelihood and derives a spatial prior based on thin-plate splines.

**License** GPL (>= 3)

**URL** <https://github.com/gentrywhite/DSSP>

**BugReports** <https://github.com/gentrywhite/DSSP/issues>

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DSSP-package

*Implementation of the Direct Sampling Spatial Prior*

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### Description

Draw samples from the direct sampling spatial prior model as described in G. White, D. Sun, P. Speckman (2019) <arXiv:1906.05575>. The basic model assumes a Gaussian likelihood and derives a spatial prior based on thin-plate splines.

### Package Content

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DSSP

*DSSP***Description**

This function samples from the log-posterior of all parameters in the model and returns a list object containing the samples. It performs a few compatibility checks on the inputs, then calls the `sample.eta()`, `sample.delta()`, and `sample.nu()`.

**Usage**

```
DSSP(formula, data, N, pars, log_prior = function(x) -x, coords = NULL)
```

**Arguments**

|                        |  |
|------------------------|--|
| <code>formula</code>   | a two sided linear formula with the response on left and the covariates on the right.  |
| <code>data</code>      | a <code>data.frame</code> or <code>sp::SpatialPointsDataFrame</code> containing the response variable, covariates and coordinates.                     |
| <code>N</code>         | is the number of random samples to be drawn from the joint posterior for eta, delta, and nu.   |
| <code>pars</code>      | a vector of the prior shape and rate parameters for the inverse-gamma prior distribution of delta, the variance parameter for the Gaussian likelihood. |
| <code>log_prior</code> | a function evaluating the log of the prior density of eta. Default to be <code>function(x) -x</code> .   |
| <code>coords</code>    | spatial coordinates passed as the value argument to <code>sp::coordinates()</code> .   |

**Details**

The direct sampling spatial prior model assumes that the spatial model can be written as the likelihood parameterised with mean vector  $\nu$  and variance  $\delta$

$$(y|\nu, \delta) N(\nu, \delta * I)$$

where  $I$  is the identity matrix. The prior for the vector of spatial effects  $\nu$  is improper but is proportional to

$$\pi(\nu|\eta) \propto (\det(M)/2\pi)^{1/2} * \exp(-\eta \nu' M \nu / 2),$$

the prior for  $\delta$  is assumed to be a inverse-gamma distribution

$$(\delta) IG(a, b)$$

and the prior for  $\eta$  can be specified for the user as any valid density function for  $\eta > 0$ .

**Value**

A list containing  $N$  samples of  $\nu$ ,  $\eta$ ,  $\delta$ , and the original data  $X$  and  $Y$ .

## Examples

```
## Use the Meuse River dataset from the package 'gstat'

library(sp)
library(gstat)
data(meuse.all)
coordinates(meuse.all) <- ~ x + y

f <- function(x) -x ## log-prior for exponential distribution for the smoothing parameter

## Draw 100 samples from the posterior of eta given the data y.
OUTPUT <- DSSP(
  formula = log(zinc) ~ 1, data = meuse.all, N = 100,
  pars = c(0.001, 0.001), log_prior = f
)
```

---

make.M

*Precision Matrix Function*

---

## Description

This function creates the precision matrix for the spatial prior based on thin-plate splines and returns the matrix M, and its eigenvalues and eigenvectors

## Usage

```
make.M(X, covariates)
```

## Arguments

|            |  |
|------------|--|
| X          | a matrix of spatial coordinates. It is recommended that the coordinates be scaled and centred. |
| covariates | the observed values for the covariates (including intercept).                                  |

## Details

The M matrix is the precision matrix for the spatial effects from the direct sampling spatial prior (DSSP) model. M is based on thin plate splines basis functions, see White et. al. 2019 for more details on how the matrix M is constructed.

## Value

A list containing the precision matrix M and the object M.eigen containing eigenvalues and eigenvectors for the matrix M.

**Examples**

```
## Use the Meuse River dataset from the package 'gstat'

library(sp)
library(gstat)
data(meuse.all)
coordinates(meuse.all) <- ~ x + y
X <- scale(coordinates(meuse.all))
make.M(X)
```

---

plot.dsspMod

*Diagnostic, Density and Contour Plots*


---

**Description**

Diagnostic, Density and Contour Plots

**Usage**

```
## S3 method for class 'dsspMod'
plot(
  x,
  robust_residuals = TRUE,
  contour_plots = TRUE,
  nx = 100,
  ny = 100,
  nlevels = 5,
  ...
)
```

**Arguments**

|                  |  |
|------------------|--|
| x                | an object of class dsspMod   |
| robust_residuals | whether to use robust residuals (median of predicted). Default to be TRUE.         |
| contour_plots    | whether or not to return a second panel with contour plots. Defaults to TRUE       |
| nx               | dimension of output grid in x direction. Used for interpolation (akime::interp()). |
| ny               | dimension of output grid in y direction. Used for interpolation (akime::interp()). |
| nlevels          | number of levels used in contour plot.   |
| ...              | additional arguments that are passed to ggplot2::scale_fill_distiller().           |

**Value**

a list containing the plots printed (individually and together in grid)

**Examples**

```

library(sp)
library(gstat)
data(meuse.all)
coordinates(meuse.all) <- ~ x + y

f <- function(x) -x ## log-prior for exponential distribution for the smoothing parameter

## Draw 100 samples from the posterior of eta given the data y.
OUTPUT <- DSSP(
  formula = log(zinc) ~ 1, data = meuse.all, N = 100,
  pars = c(0.001, 0.001), log_prior = f
)
plot(OUTPUT, contour_plots = FALSE)

```

---

|                 |  |
|-----------------|--|
| predict.dsspMod | <i>Predictions from a model with new data.</i> |
|-----------------|--|

---

**Description**

Predictions from a model with new data.

**Usage**

```

## S3 method for class 'dsspMod'
predict(object, newdata, ...)

```

**Arguments**

|         |   |
|---------|---|
| object  | a fitted dsspMod object.                        |
| newdata | a data frame for which to evaluate predictions. |
| ...     | optional and ignored arguments.                 |

**Value**

returns matrix with posterior densities for each row in the input data.

**Examples**

```

data("meuse.all", package = "gstat")
sp::coordinates(meuse.all) <- ~ x + y
meuse.fit <- DSSP(
  formula = log(zinc) ~ 1, data = meuse.all[1:155, ], N = 100, function(x) -2 * log(1 + x),
  pars = c(0.001, 0.001)
)
preds <- predict(meuse.fit, meuse.all[156:164, ])

```

---

|                   |   |
|-------------------|---|
| residuals.dsspMod | <i>Get residuals from dsspMod model</i> |
|-------------------|---|

---

## Description

Get residuals from dsspMod model

## Usage

```
## S3 method for class 'dsspMod'  
residuals(object, newdata, robust = TRUE, ...)
```

## Arguments

|         |  |
|---------|--|
| object  | an object of class dsspMod   |
| newdata | a data frame for which to estimate residuals.  |
| robust  | whether or not to use median (rather than mean) of posterior density to as estimate calculate residuals. |
| ...     | additional arguments which are ignored.  |

## Value

vector containing residuals with same length as rows in data used.

## Examples

```
library(sp)  
library(gstat)  
data(meuse.all)  
coordinates(meuse.all) <- ~ x + y  
  
f <- function(x) -x ## log-prior for exponential distribution for the smoothing parameter  
  
## Draw 100 samples from the posterior of eta given the data y.  
OUTPUT <- DSSP(  
  formula = log(zinc) ~ 1, data = meuse.all, N = 100,  
  pars = c(0.001, 0.001), log_prior = f  
)  
residuals(OUTPUT)
```

---

sample.delta

*Function to sample from the posterior of the variance parameter*


---

### Description

This function samples from the log-posterior density of the variance parameter from the likelihood

### Usage

```
sample.delta(eta, ND, EV, Q, pars)
```

### Arguments

|      |  |
|------|--|
| eta  | samples of the smoothing parameter from the sample.eta function.                                   |
| ND   | the rank of the precision matrix, the default value is n-3 for spatial data.                       |
| EV   | eigenvalues of the precision matrix spatial prior from the function make.M().                      |
| Q    | the data vector from the cross-product of observed data, Y, and eigenvalues from the M matrix, V.  |
| pars | a vector of the prior shape and rate parameters for the inverse-gamma prior distribution of delta. |

### Value

N samples drawn from the posterior of  $\pi(\text{delta}|\text{eta}, y)$ .

### Examples

```
## Use the Meuse River dataset from the package 'gstat'

library(sp)
library(gstat)
data(meuse.all)
coordinates(meuse.all) <- ~ x + y
X <- scale(coordinates(meuse.all))
tmp <- make.M(X)

M <- tmp$M

Y <- scale(log(meuse.all$zinc))

ND <- nrow(X) - 3
M.list <- make.M(X) ## Only Needs to return the eigenvalues and vectors
M <- M.list$M
EV <- M.list$M.eigen$values
V <- M.list$M.eigen$vectors
Q <- crossprod(Y, V)

f <- function(x) -x ## log-prior for exponential distribution for the smoothing parameter
```



```

## Draw 100 samples from the posterior of eta given the data y.

ETA <- sample.eta(100, ND, EV, Q, f, UL = 1000)
DELTA <- sample.delta(ETA, ND, EV, Q, pars = c(0.001, 0.001))
## Old Slow Version of sample.nu()
## sample.delta<-function(eta,nd,ev,Q,pars)
## {
##   N<-length(eta)
##   f.beta<-function(x)
##   {
##     lambda<-1/(1+x*ev)
##     b<-tcrossprod(Q,diag(1-lambda))
##     beta<-0.5*tcrossprod(Q,b)+pars[2]
##     return(beta)
##   }
##   alpha<-pars[1]+nd*0.5
##   beta<-sapply(eta,f.beta)
##   delta<-1/rgamma(N,shape=alpha,rate=beta)
##   return(delta)
## }

```

---

sample.eta

*Function to sample from the posterior of the smoothing parameter eta conditioned on the data y.*

---

### Description

This function samples from the log-posterior density of the smoothing parameter from the thin-plate splines based spatial prior using a ratio-of-uniform sampler.

### Usage

```
sample.eta(N, ND, EV, Q, UL = 1000, log_prior)
```

### Arguments

|           |  |
|-----------|--|
| N         | the number of samples desired.   |
| ND        | the rank of the precision matrix, the default value is n-3 for spatial data.                               |
| EV        | eigenvalues of the precision matrix spatial prior from the function make.M().                              |
| Q         | the data vector from the cross-product of observed data, Y, and eigenvalues from the M matrix, V.          |
| UL        | the upper limit for the smoothing parameter value; used for the ratio-of-uniform sampler, default is 1000. |
| log_prior | a function of x evaluating the log of the prior density for eta  |

### Value

N samples drawn from the posterior of eta given the data y  $\pi(\eta|y)$ .

## Examples

```
## Use the Meuse River dataset from the package 'gstat'

library(sp)
library(gstat)
data(meuse.all)
coordinates(meuse.all) <- ~ x + y
X <- scale(coordinates(meuse.all))
tmp <- make.M(X)

EV <- tmp$M.eigen$values
V <- tmp$M.eigen$vectors

M <- tmp$M

Y <- scale(log(meuse.all$zinc))
Q <- crossprod(Y, V)

ND <- nrow(X) - 3
f <- function(x) -x ## log-prior for exponential distribution for the smoothing parameter

## Draw 100 samples from the posterior of eta given the data y.
sample.eta(100, ND, EV, Q, UL = 1000, f)
```

---

sample.nu

*Function to sample from the posterior of the spatial effects*

---

## Description

This function samples from the posterior density of the spatial effects from the direct sampling spatial prior (DSSP) model.

## Usage

```
sample.nu(Y, eta, delta, EV, V)
```

## Arguments

|       |  |
|-------|--|
| Y     | vector of observed data.   |
| eta   | samples of the smoothing parameter from the sample.eta function.               |
| delta | samples of the variance parameter from the sample.delta function.              |
| EV    | eigenvalues of the precision matrix spatial prior from the function make.M().  |
| V     | eigenvectors of the precision matrix spatial prior from the function make.M(). |

## Value

A matrix of samples with each column a random draw from the posterior of the spatial effects from the DSSP model  $\pi(nu|eta, delta, y)$ .

**Examples**

```
## Use the Meuse River dataset from the package 'gstat'

library(sp)
library(gstat)
data(meuse.all)
coordinates(meuse.all) <- ~ x + y
X <- scale(coordinates(meuse.all))
tmp <- make.M(X)

EV <- tmp$M.eigen$values
V <- tmp$M.eigen$vectors

Y <- scale(log(meuse.all$zinc))
Q <- crossprod(Y, V)

ND <- nrow(X) - 3
f <- function(x) -x ## log-prior for exponential distribution for the smoothing parameter
## Draw 100 samples from the posterior of eta given the data y.

ETA <- sample.eta(100, ND, EV, Q, f, UL = 1000)
DELTA <- sample.delta(ETA, ND, EV, Q, pars = c(0.001, 0.001))
NU <- sample.nu(Y, ETA, DELTA, EV, V)
```

summary.dsspMod

*Summarise a dsspMod model***Description**

Summarise a dsspMod model

**Usage**

```
## S3 method for class 'dsspMod'
summary(object, prob = 0.95, robust = FALSE, mc_se = FALSE, ...)
```

**Arguments**

|        |  |
|--------|--|
| object | an object of class dsspMod   |
| prob   | the desired probability to be covered by the credible intervals. The default is 0.95.  |
| robust | whether or not to use the median (rather than the mean) to calculate the estimates that summarise the posterior. Default to FALSE. |
| mc_se  | whether or not to include the uncertainty in Estimate caused by sampling should be shown in the summary. Defaults to FALSE.        |
| ...    | additional arguments which are ignored.  |

**Value**

An object of class "dsspModsummary". Provides a summary of the the Direct Sampling Spatial Prior (DSSP) model. Includes details of the formula used to fit the model, and a summary of the model (*eta*, *delta*) and the covariates.

**Examples**

```
library(sp)
library(gstat)
data(meuse.all)
coordinates(meuse.all) <- ~ x + y

f <- function(x) -x ## log-prior for exponential distribution for the smoothing parameter

## Draw 100 samples from the posterior of eta given the data y.
OUTPUT <- DSSP(
  formula = log(zinc) ~ 1, data = meuse.all, N = 100,
  pars = c(0.001, 0.001), log_prior = f
)
summary(OUTPUT)
```

---

 tps.rbf

*TPS radial basis function*


---

**Description**

Function to compute the thin-plate splines radial basis function for internal use by the function `make.M()`.

**Usage**

```
tps.rbf(x, is.even)
```

**Arguments**

|                      |   |
|----------------------|---|
| <code>x</code>       | is a Euclidean distance between two points.   |
| <code>is.even</code> | is a logical argument indicating TRUE if the dimension of the space where the thin-plate spline smoother is being fitted is even. |

**Details**

This function computes the thin-plate spline radial basis function depending on the if `d` is odd or even.

**Value**

The resulting value of the thin-plate spline radial basis function.

**Examples**

```
## Use the Meuse River dataset from the package 'gstat'  
  
library(sp)  
library(gstat)  
data(meuse.all)  
coordinates(meuse.all) <- ~ x + y  
X <- scale(coordinates(meuse.all))  
D <- as.matrix(dist(X))  
K <- tps.rbf(D, TRUE)
```

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