Package ‘fourierin’

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Type Package

Title Computes Numeric Fourier Integrals

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Description
Computes Fourier integrals of functions of one and two variables using the Fast Fourier transform. The Fourier transforms must be evaluated on a regular grid for fast evaluation.

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LinkingTo RcppArmadillo, Rcpp

Imports Rcpp (>= 1.0.1),

Suggests MASS, knitr, rmarkdown, dplyr, tidyr, purrr, ggplot2, lattice, rbenchmark, testthat (>= 3.1.0), covr, spelling

RoxygenNote 7.2.3

URL https://github.com/gbasulto/fourierin

BugReports https://github.com/gbasulto/fourierin/issues

VignetteBuilder knitr

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`fourierin` *Compute Fourier integrals*

Description

It computes Fourier integrals for functions of one and two variables.

Usage

```
fourierin(
  f,
  lower_int,
  upper_int,
  lower_eval = NULL,
  upper_eval = NULL,
  const_adj,
  freq_adj,
  resolution = NULL,
  eval_grid = NULL,
  use_fft = TRUE
)
```

Arguments

`f`	function or a vector of size m. If a function is provided, it must be able to be evaluated at vectors. If a vector of values is provided, such evaluations must have been obtained on a regular grid and the Fourier integral is faster is m is a power of 2.
`lower_int`	Lower integration limit(s).
`upper_int`	Upper integration limit(s).
`lower_eval`	Lower evaluation limit(s). It can be NULL if an evaluation grid is provided.
`upper_eval`	Upper evaluation limit(s). It can be NULL if an evaluation grid is provided.
`const_adj`	Factor related to adjust definition of Fourier transform. It is usually equal to 0, -1 or 1.
`freq_adj`	Constant to adjust the exponent on the definition of the Fourier transform. It is usually equal to 1, -1, 2pi or -2pi.
`resolution`	A vector of integers (faster if powers of two) determining the resolution of the evaluation grid. Not required if f is a vector.
`eval_grid`	Optional matrix with d columns with the points where the Fourier integral will be evaluated. If it is provided, the FFT will not be used.
`use_fft`	Logical value specifying whether the FFT will be used.

Details

See plenty of detailed examples in the vignette.

Value

A list with the elements n-dimensional array and n vectors with their corresponding resolution. Specifically,

`values` A n-dimensional (resol_1 x resol_2 x ... x resol_n) complex array with the values.

`w1` A vector of size resol_1

`...`

`wn` A vector of size resol_n

Examples

```
##--- Example 1 ---------------------------------------------------
##--- Recovering std. normal from its characteristic function -----
library(fourierin)

## Function to be used in the integrand
myfnc <- function(t) exp(-t^2/2)

## Compute integral
out <- fourierin(f = myfnc, lower_int = -5, upper_int = 5,
                 lower_eval= -3, upper_eval = 3, const_adj = -1,
                 freq_adj = -1, resolution = 64)

## Extract grid and values
grid <- out$w
values <- Re(out$values)

## Compare with true values of Fourier transform
plot(grid, values, type = "l", col = 3)
lines(grid, dnorm(grid), col = 4)


##--- Example 2 ---------------------------------------------------
##--- Computing characteristic function of a gamma r. v. ----------

library(fourierin)

## Function to be used in integrand
myfnc <- function(t) dgamma(t, shape, rate)

## Compute integral
shape <- 5
rate <- 3
out <- fourierin(f = myfnc, lower_int = 0, upper_int = 6,
                 lower_eval = -4, upper_eval = 4,
                 const_adj = 1, freq_adj = 1, resolution = 64)

## Extract values
grid <- out$w                          # Extract grid
re_values <- Re(out$values)            # Real values
```

```
im_values <- Im(out$values)             # Imag values

## Now compute the real and imaginary true values of the
## characteric function.
true_cf <- function(t, shape, rate) (1 - 1i*t/rate)^-shape
true_re <- Re(true_cf(grid, shape, rate))
true_im <- Im(true_cf(grid, shape, rate))

## Compare them. We can see a slight discrepancy on the tails,
## but that is fixed when resulution is increased.
plot(grid, re_values, type = "l", col = 3)
lines(grid, true_re, col = 4)

                                        # Same here
plot(grid, im_values, type = "l", col = 3)
lines(grid, true_im, col = 4)

##--- Example 3 -------------------------------------------------
##--- Recovering std. normal from its characteristic function ---
library(fourierin)

##-Parameters of bivariate normal distribution
mu <- c(-1, 1)
sig <- matrix(c(3, -1, -1, 2), 2, 2)

##-Multivariate normal density
##-x is n x d
f <- function(x) {
    ##-Auxiliar values
    d <- ncol(x)
    z <- sweep(x, 2, mu, "-")
    ##-Get numerator and denominator of normal density
    num <- exp(-0.5*rowSums(z * (z %*% solve(sig))))
    denom <- sqrt((2*pi)^d*det(sig))
    return(num/denom)
}

## Characteristic function
## s is n x d
phi <- function(s) {
    complex(modulus = exp(- 0.5*rowSums(s*(s %*% sig))),
            argument = s %*% mu)
}

##-Approximate cf using Fourier integrals
eval <- fourierin(f, lower_int = c(-8, -6), upper_int = c(6, 8),
                  lower_eval = c(-4, -4), upper_eval = c(4, 4),
                  const_adj = 1, freq_adj =  1,
                  resolution = c(128, 128))

## Extract values
t1 <- eval$w1
t2 <- eval$w2
```

```
t <- as.matrix(expand.grid(t1 = t1, t2 = t2))
approx <- eval$values
true <- matrix(phi(t), 128, 128)        # Compute true values


## This is a section of the characteristic function
i <- 65
plot(t2, Re(approx[i, ]), type = "l", col = 2,
     ylab = "",
     xlab = expression(t[2]),
     main = expression(paste("Real part section at ",
                             t[1], "= 0")))
lines(t2, Re(true[i, ]), col = 3)
legend("topleft", legend = c("true", "approximation"),
       col = 3:2, lwd = 1)

##-Another section, now of the imaginary part
plot(t1, Im(approx[, i]), type = "l", col = 2,
     ylab = "",
     xlab = expression(t[1]),
     main = expression(paste("Imaginary part section at ",
                             t[2], "= 0")))
lines(t1, Im(true[, i]), col = 3)
legend("topleft", legend = c("true", "approximation"),
       col = 3:2, lwd = 1)
```

fourierin_1d *Univariate Fourier integrals*

Description

It computes Fourier integrals of functions of one and two variables on a regular grid.

Usage

```
fourierin_1d(
  f,
  lower_int,
  upper_int,
  lower_eval = NULL,
  upper_eval = NULL,
  const_adj,
  freq_adj,
  resolution = NULL,
  eval_grid = NULL,
  use_fft = TRUE
)
```

Arguments

- `f`: function or a vector of size m. If a function is provided, it must be able to be evaluated at vectors. If a vector of values is provided, such evaluations must have been obtained on a regular grid and the Fourier integral is faster is m is a power of 2.
- `lower_int`: Lower integration limit(s).
- `upper_int`: Upper integration limit(s).
- `lower_eval`: Lower evaluation limit(s). It can be NULL if an evaluation grid is provided.
- `upper_eval`: Upper evaluation limit(s). It can be NULL if an evaluation grid is provided.
- `const_adj`: Factor related to adjust definition of Fourier transform. It is usually equal to 0, -1 or 1.
- `freq_adj`: Constant to adjust the exponent on the definition of the Fourier transform. It is usually equal to 1, -1, 2pi or -2pi.
- `resolution`: A vector of integers (faster if powers of two) determining the resolution of the evaluation grid. Not required if f is a vector.
- `eval_grid`: Optional matrix with d columns with the points where the Fourier integral will be evaluated. If it is provided, the FFT will not be used.
- `use_fft`: Logical value specifying whether the FFT will be used.

Details

See vignette for more detailed examples.

Value

If w is given, only the values of the Fourier integral are returned, otherwise, a list with the elements

- `w`: A vector of size m where the integral was computed.
- `values`: A complex vector of size m with the values of the integral

Examples

```
##--- Example 1 ---------------------------------------------------
##--- Recovering std. normal from its characteristic function -----
library(fourierin)

#' Function to to be used in integrand
myfun <- function(t) exp(-t^2/2)

                                        # Compute Foueien integral
out <- fourierin_1d(f = myfun,
                    lower_int = -5, upper_int = 5,
                    lower_eval = -3, upper_eval = 3,
                    const_adj = -1, freq_adj = -1,
                    resolution = 64)

## Extract grid and values
```

```
grid <- out$w
values <- Re(out$values)

plot(grid, values, type = "l", col = 3)
lines(grid, dnorm(grid), col = 4)

##--- Example 2 ---------------------------------------------
##--- Computing characteristic function of a gamma r. v. ------

library(fourierin)

## Function to to be used in integrand
myfun <- function(t) dgamma(t, shape, rate)

## Compute integral
shape <- 5
rate <- 3
out <- fourierin_1d(f = myfun, lower_int = 0, upper_int = 6,
                    lower_eval = -4, upper_eval = 4,
                    const_adj = 1, freq_adj = 1, resolution = 64)

grid <- out$w                          # Extract grid
re_values <- Re(out$values)            # Real values
im_values <- Im(out$values)            # Imag values

                                     # Now compute the real and
                                     # imaginary true values of the
                                        # characteristic function.
true_cf <- function(t, shape, rate) (1 - 1i*t/rate)^-shape
true_re <- Re(true_cf(grid, shape, rate))
true_im <- Im(true_cf(grid, shape, rate))

                                     # Compare them. We can see a
                                     # slight discrepancy on the
                                     # tails, but that is fixed
                                     # when resulution is
                                     # increased.
plot(grid, re_values, type = "l", col = 3)
lines(grid, true_re, col = 4)

                                        # Same here
plot(grid, im_values, type = "l", col = 3)
lines(grid, true_im, col = 4)
```

`fourierin_2d` *Bivariate Fourier integrals*

Description

It computes Fourier integrals for functions of one and two variables.

Usage

```
fourierin_2d(
  f,
  lower_int,
  upper_int,
  lower_eval = NULL,
  upper_eval = NULL,
  const_adj,
  freq_adj,
  resolution = NULL,
  eval_grid = NULL,
  use_fft = TRUE
)
```

Arguments

`f`	function or a vector of size m. If a function is provided, it must be able to be evaluated at vectors. If a vector of values is provided, such evaluations must have been obtained on a regular grid and the Fourier integral is faster is m is a power of 2.
`lower_int`	Lower integration limit(s).
`upper_int`	Upper integration limit(s).
`lower_eval`	Lower evaluation limit(s). It can be NULL if an evaluation grid is provided.
`upper_eval`	Upper evaluation limit(s). It can be NULL if an evaluation grid is provided.
`const_adj`	Factor related to adjust definition of Fourier transform. It is usually equal to 0, -1 or 1.
`freq_adj`	Constant to adjust the exponent on the definition of the Fourier transform. It is usually equal to 1, -1, 2pi or -2pi.
`resolution`	A vector of integers (faster if powers of two) determining the resolution of the evaluation grid. Not required if f is a vector.
`eval_grid`	Optional matrix with d columns with the points where the Fourier integral will be evaluated. If it is provided, the FFT will not be used.
`use_fft`	Logical value specifying whether the FFT will be used.

Value

If w is given, only the values of the Fourier integral are returned, otherwise, a list with three elements

`w1`	Evaluation grid for first entry
`w2`	Evaluation grid for second entry
`values`	m1 x m2 matrix of complex numbers, corresponding to the evaluations of the integral

Examples

```
##--- Recovering std. normal from its characteristic function -----
library(fourierin)

##-Parameters of bivariate normal distribution
mu <- c(-1, 1)
sig <- matrix(c(3, -1, -1, 2), 2, 2)

##-Multivariate normal density
##-x is n x d
f <- function(x) {
    ##-Auxiliar values
    d <- ncol(x)
    z <- sweep(x, 2, mu, "-")

    ##-Get numerator and denominator of normal density
    num <- exp(-0.5*rowSums(z * (z %*% solve(sig))))
    denom <- sqrt((2*pi)^d*det(sig))

    return(num/denom)
}

##-Characteristic function
##-s is n x d
phi <- function(s) {
    complex(modulus = exp(- 0.5*rowSums(s*(s %*% sig))),
            argument = s %*% mu)
}

##-Approximate cf using Fourier integrals
eval <- fourierin_2d(f, lower_int = c(-8, -6), upper_int = c(6, 8),
                     lower_eval = c(-4, -4), upper_eval = c(4, 4),
                     const_adj = 1, freq_adj =  1,
                     resolution = c(128, 128))

## Extract values
t1 <- eval$w1
t2 <- eval$w2
t <- as.matrix(expand.grid(t1 = t1, t2 = t2))
approx <- eval$values
true <- matrix(phi(t), 128, 128)        # Compute true values

##-This is a section of the characteristic functions
i <- 65
plot(t2, Re(approx[i, ]), type = "l", col = 2,
     ylab = "",
     xlab = expression(t[2]),
     main = expression(paste("Real part section at ",
                             t[1], "= 0")))
lines(t2, Re(true[i, ]), col = 3)
legend("topleft", legend = c("true", "approximation"),
       col = 3:2, lwd = 1)
```

```
##-Another section, now of the imaginary part
plot(t1, Im(approx[, i]), type = "l", col = 2,
     ylab = "",
     xlab = expression(t[1]),
     main = expression(paste("Imaginary part section at ",
                             t[2], "= 0")))
lines(t1, Im(true[, i]), col = 3)
legend("topleft", legend = c("true", "approximation"),
       col = 3:2, lwd = 1)
```

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