Test PMLSeg

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Introduction

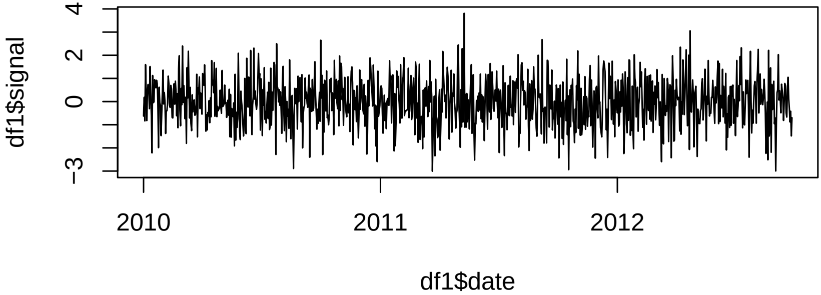
This document presents results from several tests of the `PMLSeg` package, including:

- Test of the `Segmentation` function with and without offsets, considering the following examples:
  - Ex1 : zero mean + IID noise
  - Ex2 : periodic mean + IID noise
  - Ex3 : periodic mean + monthly variance
- Tests of other functions such as:
  - `PlotSeg` to visualize segmentation results
  - `Cluster_screening` to detect groups of close change-points (usually due to outliers) and determine whether to keep or remove the cluster. The cluster in this document is determined by a group of close change-points within 80 days (this threshold is changeable).
  - `Validation` to validate the detected change-points with the help of metadata.

Generate Example Data

Ex1 time series

```
set.seed(1)
length_series = 1000
df1 = data.frame(date = seq.Date(from = as.Date("2010-01-01"),
                                 to = as.Date("2010-01-01")+(length_series-1),
                                 by = "day"),
                signal = rnorm(n = length_series, mean = 0, sd = 1))

plot(df1$date, df1$signal, type = "l")
```

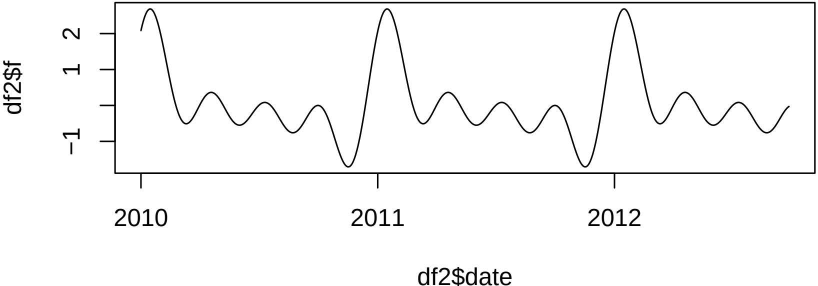


```
head(df1, 3)
#>         date     signal
#> 1 2010-01-01 -0.6264538
#> 2 2010-01-02  0.1836433
#> 3 2010-01-03 -0.8356286
```

Generate Example Data

Ex2 time series : Add the functional with 4 Fourier series components, each with a coefficient of 0.5

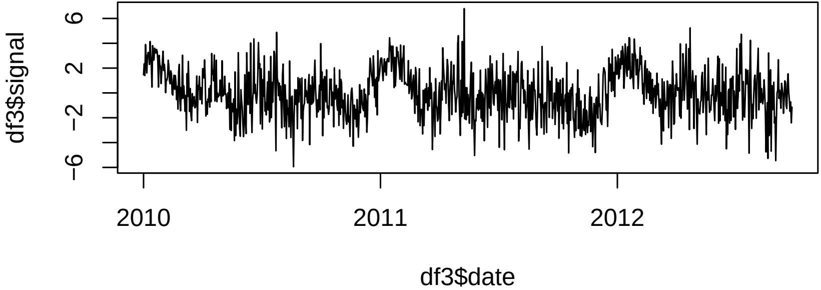
```
library(dplyr)

T <- 365.25
df2 <- df1 %>%
  mutate(t = as.numeric(date - date[1])+1,
  f = rowSums(sapply(1:4, function(i) 0.5*cos(i*t*(2*pi)/T) + 0.5*sin(i*t*(2*pi)/T))),
  signal = signal + f)

head(df2, 3)
#>         date   signal t        f
#> 1 2010-01-01 1.457297 1 2.083751
#> 2 2010-01-02 2.346461 2 2.162818
#> 3 2010-01-03 1.401342 3 2.236970
plot(df2$date, df2$f, type = "l")
```



Generate Example Data

Ex3 time series : Apply the same functional as Ex2, adjusted for monthly variance

```
std = c(1, 1.2, 1.4, 1.6, 1.8, 2, 2, 1.8, 1.6, 1.5, 1.4, 1.3)

df3 <- df1 %>%
  mutate(sd = std[as.numeric(format(date, "%m"))],
         signal = signal * sd ) %>%
  mutate(signal = signal + df2$f)

head(df3, 3)
#>         date   signal sd
#> 1 2010-01-01 1.457297  1
#> 2 2010-01-02 2.346461  1
#> 3 2010-01-03 1.401342  1
plot(df3$date, df3$signal, type = "l")
```



Generate Example Data

Harmonize Formats of 3 Dataframes for Testing

```r
df2 <- df2 %>% select(date, signal)
df3 <- df3 %>% select(date, signal)

names(df1)
#> [1] "date"   "signal"
names(df2)
#> [1] "date"   "signal"
names(df3)
#> [1] "date"   "signal"
```

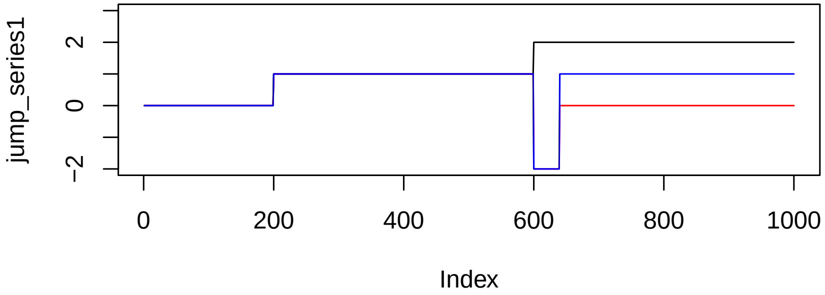
Preliminary Settings

Generate different offset series to add to the original series :

```r
# Function to generate jump series
generate_jump_series <- function(jump_indices, jump_amp, length_series) {
  jump_series <- rep(0, length_series)
  jump_indices <- c(1, jump_indices, length_series + 1)

  changes <- rep(0, length_series)
  changes[jump_indices[-length(jump_indices)]] <- jump_amp

  jump_series <- cumsum(changes)

  return(jump_series)
}
# No cluster
jump_ind1 <- c(200, 600)
jump_amp1 <- c(0, 1, 1)
# One cluster formed by the second and third change-points, which need to be
# replaced by the middle point
jump_ind2 <- c(200, 600, 640)
jump_amp2 <- c(0, 1, -3, 2)
# One cluster formed by the second and third change-points, which need to be removed
jump_amp3 <- c(0, 1, -3, 3)
```

Premilinary setting

```r
# Generate jump series
jump_series1 <- generate_jump_series(jump_ind1, jump_amp1, length_series)
jump_series2 <- generate_jump_series(jump_ind2, jump_amp2, length_series)
jump_series3 <- generate_jump_series(jump_ind2, jump_amp3, length_series)
# Visualize jump series
plot(jump_series1, type = "l", ylim = c(-2,3))
lines(jump_series2, col = "red")
lines(jump_series3, col = "blue")
```



Premilinary setting

```r
# Create an example metadata
meta = data.frame(date = c(df1$date[jump_ind2], df1$date[400]),
                  type = c("type1", "type2", "type3", "type3"))
meta
#>         date  type
#> 1 2010-07-19 type1
#> 2 2011-08-23 type2
#> 3 2011-10-02 type3
#> 4 2011-02-04 type3
```

Testing the Segmentation Function

When the series is homogeneous

```
library(PMLseg)
# Ex1
seg1a = Segmentation(OneSeries = df1, FunctPart = FALSE)
str(seg1a)
#> List of 5
#>  $ Tmu     :'data.frame':    1 obs. of  5 variables:
#>   ..$ begin: int 1
#>   ..$ end  : int 1000
#>   ..$ mean : num -0.00423
#>   ..$ se   : num 0.0336
#>   ..$ np   : num 1000
#>  $ FitF    : logi FALSE
#>  $ CoeffF  : logi FALSE
#>  $ MonthVar: num [1:12] 1.089 0.887 1.334 1.092 1.21 ...
#>  $ SSR     : num 933
seg1a$Tmu
#>   begin  end         mean         se   np
#> 1     1 1000 -0.004229094 0.03363045 1000
```

No change-points are detected, as shown in the Tmu dataframe, which lists all segments of the series. The mean is close to 0. Additionally, the results include not only the Tmu dataframe but also other outputs such as the fitted functional part FitF (which is not fitted when FunctPart is set to FALSE), coefficients of functional elements CoeefF, monthly variance MonthVar, and the Sum of Squares of Residuals SSR.

Test the Segmentation Function

When series is homogeneous

```
# Ex2
seg2a = Segmentation(OneSeries = df2, FunctPart = TRUE)
seg2a$Tmu
#>   begin  end         mean         se   np
#> 1     1 1000 -0.007048795 0.03366926 1000
# Ex3
seg3a = Segmentation(OneSeries = df3, FunctPart = TRUE)
seg3a$Tmu
#>   begin  end        mean        se   np
#> 1     1 1000 -0.01249977 0.0488041 1000
```

No change-points are detected in these two examples either.

Test the Segmentation Function

Adding Jump Series to the original Series and running the segmentation

```
# Ex1
df1b <- df1 %>% mutate(signal = signal + jump_series1)
seg1b = Segmentation(OneSeries = df1b, FunctPart = FALSE)
seg1b$Tmu
#>   begin  end       mean         se  np
#> 1     1  199 0.04231954 0.07503647 199
#> 2   200  598 0.99732352 0.05361806 399
#> 3   599 1000 1.96897996 0.05271989 402

# Ex2
df2b <- df2 %>% mutate(signal = signal + jump_series1)
seg2b = Segmentation(OneSeries = df2b, FunctPart = TRUE)
seg2b$Tmu
#>   begin  end       mean         se  np
#> 1     1  200 0.02694284 0.07473907 200
#> 2   201  598 0.99309421 0.05374394 398
#> 3   599 1000 1.97809762 0.05280951 402

# Ex3
df3b <- df3 %>% mutate(signal = signal + jump_series1)
seg3b = Segmentation(OneSeries = df3b, FunctPart = TRUE)
seg3b$Tmu
#>   begin  end      mean         se  np
#> 1     1  233 0.1119287 0.10001477 233
#> 2   234  601 1.0163802 0.08082727 368
#> 3   602 1000 1.9701980 0.07739899 399
```

Test the Segmentation Function

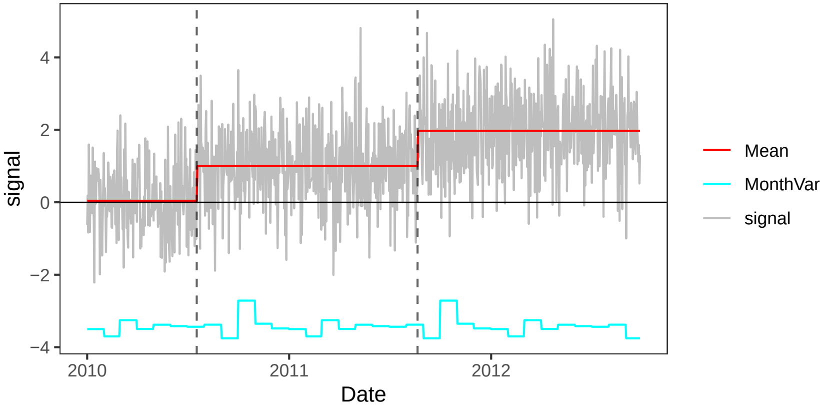
Adding other jump series in the most complicated series (Ex3)

```
df3c <- df3 %>% mutate(signal = signal + jump_series2)
seg3c = Segmentation(OneSeries = df3c, FunctPart = TRUE)
seg3c$Tmu
#>   begin  end        mean         se  np
#> 1     1  200  0.04769081 0.10420812 200
#> 2   201  599  0.99060960 0.07910378 399
#> 3   600  641 -1.92086925 0.24382647  42
#> 4   642 1000 -0.04575017 0.08162489 359

df3d <- df3 %>% mutate(signal = signal + jump_series3)
seg3d = Segmentation(OneSeries = df3d, FunctPart = TRUE)
seg3d$Tmu
#>   begin  end        mean         se  np
#> 1     1  200  0.04550598 0.10420812 200
#> 2   201  599  0.98930870 0.07913867 399
#> 3   600  639 -1.92932956 0.24728105  40
#> 4   640 1000  0.94993983 0.08153644 361
```

Test the PlotSeg Function

Visualize the segmentation result of example 1 with jump series 1

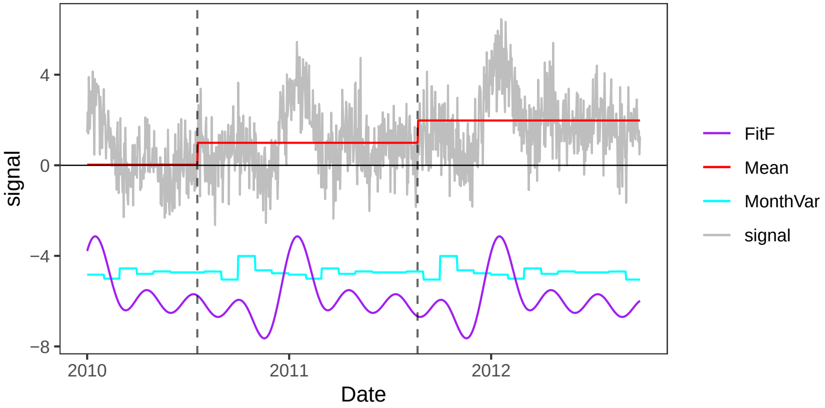
```
PlotSeg(OneSeries = df1b, SegRes = seg1b, FunctPart = FALSE)
```



Test the `PlotSeg` Function

Visualize the segmentation result of example 2 with jump series 1

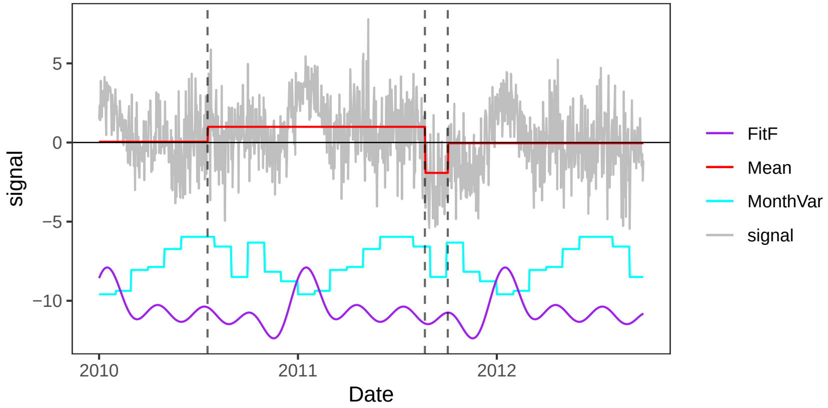
```
PlotSeg(OneSeries = df2b, SegRes = seg2b, FunctPart = TRUE)
```



Test the PlotSeg Function

Visualize the segmentation result of example 3 with with jump series 2

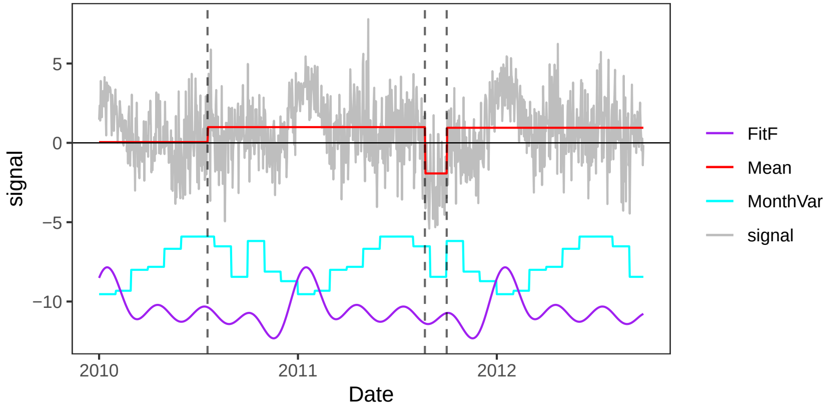
```r
PlotSeg(OneSeries = df3c, SegRes = seg3c, FunctPart = TRUE)
```



Test the PlotSeg Function

Visualize the segmentation result of example 3 with with jump series 3

```
PlotSeg(OneSeries = df3d, SegRes = seg3d, FunctPart = TRUE)
```



Test the `Cluster_screening` Function

Segmentation sometime detects the cluster like in example 3c, 3d. When it is too close and after cluster, the change in mean is not significant, we will remove such kind of cluster (`screening2`). If it is significant, we will replace a cluster by the middle point (`screening1`) and recommend to remove the data within the cluster.

```
screening1 = Cluster_screening(Tmu = seg3c$Tmu,
                               MaxDist = 80)
str(screening1)
#> List of 3
#>  $ UpdatedCP : num [1:2] 200 621
#>  $ RemoveData:'data.frame':  1 obs. of  2 variables:
#>   ..$ begin: int 600
#>   ..$ end  : int 641
#>  $ ChangeCP  : chr "Yes"

screening2 = Cluster_screening(Tmu = seg3d$Tmu,
                               MaxDist = 80)
str(screening2)
#> List of 3
#>  $ UpdatedCP : int 200
#>  $ RemoveData:'data.frame':  1 obs. of  2 variables:
#>   ..$ begin: int 600
#>   ..$ end  : int 639
#>  $ ChangeCP  : chr "Yes"
```

Test the `UpdatedParametersForFixedCP` function

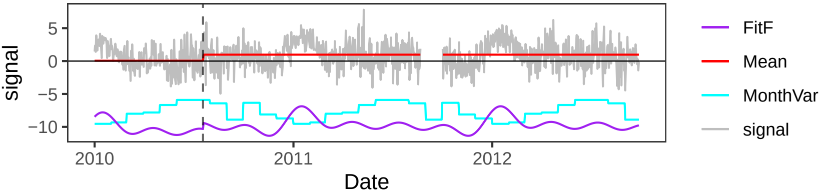
When the screening say it is needed to replace the changepoint, we need to reestimate the mean and other parameters in the `Tmu` dataframe.

```
seg_upd3c = UpdatedParametersForFixedCP(OneSeries = df3c,
                                       ResScreening = screening1)
str(seg_upd3c)
#> List of 4
#>  $ MonthVar: num [1:12] 1.06 1.28 2.6 2.79 3.92 ...
#>  $ Tmu     :'data.frame':    3 obs. of  5 variables:
#>   ..$ begin: num [1:3] 1 201 622
#>   ..$ end  : num [1:3] 200 621 1000
#>   ..$ mean : num [1:3] 0.049 0.9937 -0.0451
#>   ..$ se   : num [1:3] 0.1042 0.0782 0.0807
#>   ..$ np   : num [1:3] 200 421 379
#>  $ FitF    : Named num [1:1000] 2.14 2.22 2.3 2.37 2.44 ...
#>   ..- attr(*, "names")= chr [1:1000] "1" "2" "3" "4" ...
#>  $ CoeffF  : Named num [1:11] 0.492 0.511 0.54 0.546 0.446 ...
#>   ..- attr(*, "names")= chr [1:11] "cos1" "sin1" "cos2" "sin2" ...
seg_upd3c$Tmu
#>        begin  end        mean         se  np
#> mean_1     1  200  0.04901613 0.10420812 200
#> mean_2   201  621  0.99366883 0.07818545 421
#> mean_3   622 1000 -0.04511261 0.08072260 379

seg_upd3d = UpdatedParametersForFixedCP(OneSeries = df3d,
                                       ResScreening = screening2)
str(seg_upd3d)
#> List of 4
#>  $ MonthVar: num [1:12] 1.06 1.28 2.6 2.79 3.92 ...
#>  $ Tmu     :'data.frame':    2 obs. of  5 variables:
#>   ..$ begin: num [1:2] 1 201
#>   ..$ end  : int [1:2] 200 1000
```

Test the UpdatedParametersForFixedCP function

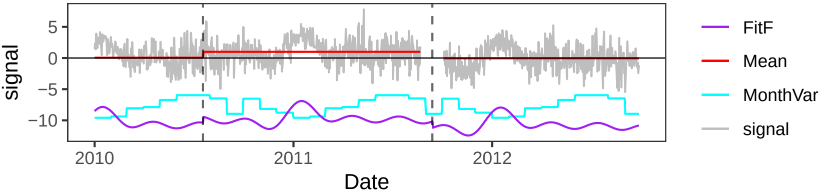
Visualize the time series after the updated segmentation

```
PlotSeg(OneSeries = df3d,
        SegRes = seg_upd3d,
        RemoveData = screening2$RemoveData)
```



Compare to the result before the cluster screening

```
PlotSeg(OneSeries = df3c,
        SegRes = seg_upd3c,
        RemoveData = screening1$RemoveData)
```



Test the UpdatedParametersForFixedCP function

Test the `Validation` function

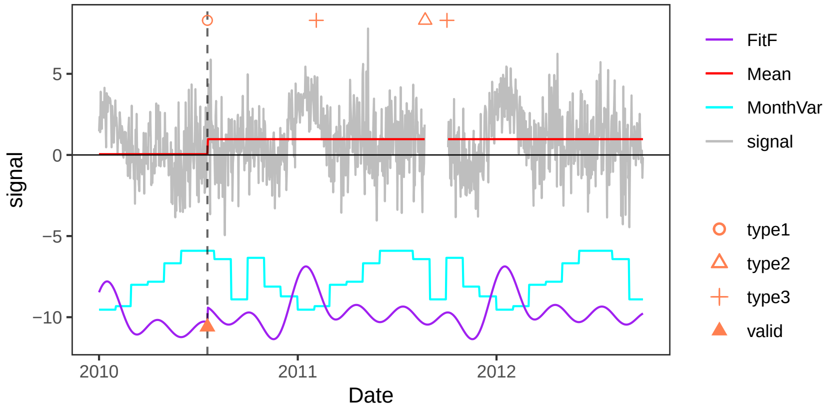
Validate the detected change-points with respect to the metadata

```
valid = Validation(OneSeries = df3d,
           Tmu = seg_upd3d$Tmu,
           MinDist = 62,
           Metadata = meta)
valid
#> # A tibble: 1 x 5
#>   CP         closestMetadata Distance type  valid
#>   <date>     <date>             <dbl> <chr> <dbl>
#> 1 2010-07-19 2010-07-19             0 type1     1
```

Test the Validation function

Visualize results with metadata

```
PlotSeg(OneSeries = df3d,
        SegRes = seg_upd3d,
        RemoveData = screening1$RemoveData,
        Metadata = meta,
        Validated_CP_Meta = valid)
```


signal
Date
FitF
Mean
MonthVar
signal
type1
type2
type3
valid