Energy Data Analysis with R

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Contents

Preface

Welcome to the introduction of energy data analysis with R.

This documents gives you a short overview of the statistical software R and their capability of analyzing data sets in the context of building monitoring data and in general of time series.

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Chapter 1

Installing R and R Studio

- Before we can start the first analysis, we have to install "R" and "RStudio".
- "R" is a programming language used for statistical computing while "RStudio" provides a graphical user interface.
- "R" may be used without "RStudio", but "RStudio" may not be used without "R". Both, "R" and "RStudio" are free of charge and there are no licencse fees.

1.1 Download and install

Installation instructions according to (Grolemund and Wickham, 2015)

1.1.1 Windows

Installation according

1.1.2 Mac

1.1.3 Linux

Chapter 2

R Basics

2.1 Packages

2.1.1 Install from CRAN

- Close all projects in R Studio
- `install.packages("ggplot2")`

2.1.2 Install from github

```
install.packages("devtools")
library(devtools)
install_github("retomarek/redutils")
```

2.1.3 Loading

- `library(ggplot2)`

2.2 Importing data

2.2.1 csv file

```
df <- read.csv("datafile.csv")
df <- read.csv("datafile.csv", header=FALSE, stringsAsFactors=FALSE)
df <- read.csv("https://github.com/retomarek/r/raw/master/datasets/buildingMonitoringTe
```

Attention: By default, strings in the data are treated as factors. read.csv() is a convenience wrapper function around read.table(). If you need more control over the input, see ?read.table

2.2.2 Excel File

```
# Only need to install once
install.packages("xlsx")

library(xslx)

df <- read.xlsx("datafile.xlsx", 1)
df <- read.xlsx("datafile.xls", sheetIndex=2)
df <- read.xlsx("datafile.xls", sheetName="Revenues")
```

For reading older Excel files in the .xls format, the gdata package has the function read.xls():

```
# Only need to install once
install.packages("gdata")

library(gdata)
# Read first sheet
df <- read.xls("datafile.xls")
df <- read.xls("datafile.xls", sheet=2)
```

Both the xlsx and gdata packages require other software to be installed on your computer. For xlsx, you need to install Java on your machine. For gdata, you need Perl, which comes as standard on Linux and Mac OS X, but not Windows. On Windows, you'll need ActiveState Perl. The Community Edition can be obtained for free.

2.3 Data manipulations

2.3.1 data frames

2.3.1.1 change row names of df

```
names(df) <- c("Column1","Column2","Column3")
```

2.3.2 wide to long

```
# wide format
head(df)
```

```
##                        time WthStnPress WthStnHum WthStnRain WthStnSolRad
## 1 2018-09-30T22:00:00.000Z     1012.30      87.0        0.8            0
## 2 2018-09-30T23:00:00.000Z     1011.90      87.5        1.1            0
## 3 2018-10-01T00:00:00.000Z     1011.45      87.5        0.5            0
## 4 2018-10-01T01:00:00.000Z     1010.90      86.5        0.5            0
## 5 2018-10-01T02:00:00.000Z     1010.55      88.0        0.6            0
## 6 2018-10-01T03:00:00.000Z     1010.20      89.0        0.1            0
##   WthStnTemp WthStnWindDir WthStnWindSpd BldgEnergyHotwater BldgEnergyHeating
## 1      12.80        157.50           3.2                  0                 0
## 2      12.35         11.25           1.6                 19                 0
## 3      11.90        146.25           2.4                  0                 0
## 4      11.90        157.50           0.8                  0                 0
## 5      11.60        146.25           2.4                  0                 0
## 6      11.75         22.50           0.8                  0                 0
##   FlatHum FlatTemp FlatVolFlowColdwater FlatVolFlowHotwater
## 1      NA       NA                0.006                   0
## 2      NA       NA                0.000                   0
## 3      NA       NA                0.000                   0
## 4      NA       NA                0.000                   0
## 5      NA       NA                0.006                   0
## 6      NA       NA                0.000                   0
```

```
# convert wide to long format
df.long <- as.data.frame(tidyr::pivot_longer(df,
                                      cols = -time,
                                      names_to = "name",
                                      values_to = "value",
                                      values_drop_na = TRUE)
                        )

# long format
head(df.long)
```

```
##                        time          name  value
## 1 2018-09-30T22:00:00.000Z   WthStnPress 1012.3
## 2 2018-09-30T22:00:00.000Z     WthStnHum   87.0
## 3 2018-09-30T22:00:00.000Z    WthStnRain    0.8
## 4 2018-09-30T22:00:00.000Z  WthStnSolRad    0.0
## 5 2018-09-30T22:00:00.000Z    WthStnTemp   12.8
## 6 2018-09-30T22:00:00.000Z WthStnWindDir  157.5
```

2.3.3 long to wide

```
# long format
head(df.long)
```

```
##                         time          name  value
## 1 2018-09-30T22:00:00.000Z   WthStnPress 1012.3
## 2 2018-09-30T22:00:00.000Z     WthStnHum   87.0
## 3 2018-09-30T22:00:00.000Z    WthStnRain    0.8
## 4 2018-09-30T22:00:00.000Z  WthStnSolRad    0.0
## 5 2018-09-30T22:00:00.000Z    WthStnTemp   12.8
## 6 2018-09-30T22:00:00.000Z WthStnWindDir  157.5
```

```
# convert long table into wide table
df.wide <- as.data.frame(tidyr::pivot_wider(df.long,
                                     names_from = "name",
                                     values_from = "value")
                         )

# wide format
head(df.wide)
```

```
##                         time WthStnPress WthStnHum WthStnRain WthStnSolRad
## 1 2018-09-30T22:00:00.000Z     1012.30      87.0        0.8            0
## 2 2018-09-30T23:00:00.000Z     1011.90      87.5        1.1            0
## 3 2018-10-01T00:00:00.000Z     1011.45      87.5        0.5            0
## 4 2018-10-01T01:00:00.000Z     1010.90      86.5        0.5            0
## 5 2018-10-01T02:00:00.000Z     1010.55      88.0        0.6            0
## 6 2018-10-01T03:00:00.000Z     1010.20      89.0        0.1            0
##   WthStnTemp WthStnWindDir WthStnWindSpd BldgEnergyHotwater BldgEnergyHeating
## 1      12.80        157.50           3.2                  0                 0
## 2      12.35         11.25           1.6                 19                 0
## 3      11.90        146.25           2.4                  0                 0
## 4      11.90        157.50           0.8                  0                 0
## 5      11.60        146.25           2.4                  0                 0
## 6      11.75         22.50           0.8                  0                 0
##   FlatVolFlowColdwater FlatVolFlowHotwater FlatHum FlatTemp
## 1                0.006                  0      NA       NA
## 2                0.000                  0      NA       NA
## 3                0.000                  0      NA       NA
## 4                0.000                  0      NA       NA
## 5                0.006                  0      NA       NA
## 6                0.000                  0      NA       NA
```

Chapter 3

Explorative Data Analysis

3.1 Get overview

Get an overview of the whole data set and specific series of it

3.1.1 Load data

Load test data set in a data frame (e.g. from a csv-file)

```
df <- read.csv("https://github.com/retomarek/r/raw/master/datasets/buildingMonitoringTestDataSet.
```

3.1.2 Names

show the column headers of the data frame

```
names(df)
```

```
##  [1] "time"                  "WthStnPress"           "WthStnHum"
##  [4] "WthStnRain"            "WthStnSolRad"          "WthStnTemp"
##  [7] "WthStnWindDir"         "WthStnWindSpd"         "BldgEnergyHotwater"
## [10] "BldgEnergyHeating"     "FlatHum"               "FlatTemp"
## [13] "FlatVolFlowColdwater" "FlatVolFlowHotwater"
```

3.1.3 Structure

show the structure of the data frame

```
str(df)
```

```
## 'data.frame':    16394 obs. of  14 variables:
##  $ time                : chr  "2018-09-30T22:00:00.000Z" "2018-09-30T23:00:00.000Z"
##  $ WthStnPress         : num  1012 1012 1011 1011 1011 ...
##  $ WthStnHum           : num  87 87.5 87.5 86.5 88 89 86.5 81 78 80.5 ...
##  $ WthStnRain          : num  0.8 1.1 0.5 0.5 0.6 0.1 0.2 0 0 0 ...
##  $ WthStnSolRad        : num  0 0 0 0 0 0 0 0 3 24.5 ...
##  $ WthStnTemp          : num  12.8 12.4 11.9 11.9 11.6 ...
##  $ WthStnWindDir       : num  157.5 11.2 146.2 157.5 146.2 ...
##  $ WthStnWindSpd       : num  3.2 1.6 2.4 0.8 2.4 0.8 0.8 3.2 4 3.2 ...
##  $ BldgEnergyHotwater  : num  0 19 0 0 0 ...
##  $ BldgEnergyHeating   : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ FlatHum             : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ FlatTemp            : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ FlatVolFlowColdwater: num  0.006 0 0 0 0.006 ...
##  $ FlatVolFlowHotwater : num  0 0 0 0 0 ...
```

3.1.4 Head/Tail

```
head(df)
```

```
##                       time WthStnPress WthStnHum WthStnRain WthStnSolRad
## 1 2018-09-30T22:00:00.000Z     1012.30      87.0        0.8            0
## 2 2018-09-30T23:00:00.000Z     1011.90      87.5        1.1            0
## 3 2018-10-01T00:00:00.000Z     1011.45      87.5        0.5            0
## 4 2018-10-01T01:00:00.000Z     1010.90      86.5        0.5            0
## 5 2018-10-01T02:00:00.000Z     1010.55      88.0        0.6            0
## 6 2018-10-01T03:00:00.000Z     1010.20      89.0        0.1            0
##   WthStnTemp WthStnWindDir WthStnWindSpd BldgEnergyHotwater BldgEnergyHeating
## 1      12.80        157.50           3.2                  0                 0
## 2      12.35         11.25           1.6                 19                 0
## 3      11.90        146.25           2.4                  0                 0
## 4      11.90        157.50           0.8                  0                 0
## 5      11.60        146.25           2.4                  0                 0
## 6      11.75         22.50           0.8                  0                 0
##   FlatHum FlatTemp FlatVolFlowColdwater FlatVolFlowHotwater
## 1      NA       NA                0.006                   0
## 2      NA       NA                0.000                   0
## 3      NA       NA                0.000                   0
## 4      NA       NA                0.000                   0
## 5      NA       NA                0.006                   0
## 6      NA       NA                0.000                   0
```

```
tail(df)
```

```
##                           time WthStnPress WthStnHum WthStnRain WthStnSolRad
## 16389 2020-08-13T18:00:00.000Z    1011.650     74.75    2.19964            9
## 16390 2020-08-13T19:00:00.000Z    1012.000     79.00    2.19964            0
## 16391 2020-08-13T20:00:00.000Z    1011.950     78.25    2.19964            0
## 16392 2020-08-13T21:00:00.000Z    1012.025     76.50    2.19964            0
## 16393 2020-08-13T22:00:00.000Z    1012.250     73.00    0.00000            0
## 16394 2020-08-13T23:00:00.000Z          NA        NA         NA           NA
##       WthStnTemp WthStnWindDir WthStnWindSpd BldgEnergyHotwater
## 16389     22.000        162.00      0.000000                 NA
## 16390     20.175        124.25      1.609340                 NA
## 16391     19.350        125.00      0.402335                 NA
## 16392     19.900         93.00      1.609340                 NA
## 16393     20.625        116.25      2.414010                 NA
## 16394         NA            NA            NA                 NA
##       BldgEnergyHeating FlatHum FlatTemp FlatVolFlowColdwater
## 16389                NA      NA       NA                   NA
## 16390                NA      NA       NA                   NA
## 16391                NA      NA       NA                   NA
## 16392                NA      NA       NA                   NA
## 16393                NA      NA       NA                   NA
## 16394                NA      NA       NA                   NA
##       FlatVolFlowHotwater
## 16389                  NA
## 16390                  NA
## 16391                  NA
## 16392                  NA
## 16393                  NA
## 16394                  NA
```

3.1.5 Five number summary

reveals details of a specific series

```
summary(df$WthStnTemp)
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.    NA's 
##   -5.25    5.50   11.25   11.99   17.35   40.30      12
```

3.2 Data Wrangling

3.2.1 season from date

```
# install redutils library
# devtools::install_github("retomarek/redutils", ref = "master")

# get season from a date
redutils::season(as.Date("2019-04-01"))
```

```
## [1] "Spring"
```

```
redutils::season(as.Date("2019-04-01"), c("Winter","Frühling","Sommer","Herbst"))
```

```
## [1] "Frühling"
```

```
# apply it for a data frame
df.season <- dplyr::mutate(df, season = redutils::season(df$time))
head(df.season)
```

```
##                       time WthStnPress WthStnHum WthStnRain WthStnSolRad
## 1 2018-09-30T22:00:00.000Z     1012.30      87.0        0.8            0
## 2 2018-09-30T23:00:00.000Z     1011.90      87.5        1.1            0
## 3 2018-10-01T00:00:00.000Z     1011.45      87.5        0.5            0
## 4 2018-10-01T01:00:00.000Z     1010.90      86.5        0.5            0
## 5 2018-10-01T02:00:00.000Z     1010.55      88.0        0.6            0
## 6 2018-10-01T03:00:00.000Z     1010.20      89.0        0.1            0
##   WthStnTemp WthStnWindDir WthStnWindSpd BldgEnergyHotwater BldgEnergyHeating
## 1      12.80        157.50           3.2                  0                 0
## 2      12.35         11.25           1.6                 19                 0
## 3      11.90        146.25           2.4                  0                 0
## 4      11.90        157.50           0.8                  0                 0
## 5      11.60        146.25           2.4                  0                 0
## 6      11.75         22.50           0.8                  0                 0
##   FlatHum FlatTemp FlatVolFlowColdwater FlatVolFlowHotwater season
## 1      NA       NA                0.006                   0   Fall
## 2      NA       NA                0.000                   0   Fall
## 3      NA       NA                0.000                   0   Fall
## 4      NA       NA                0.000                   0   Fall
## 5      NA       NA                0.006                   0   Fall
## 6      NA       NA                0.000                   0   Fall
```

Chapter 4

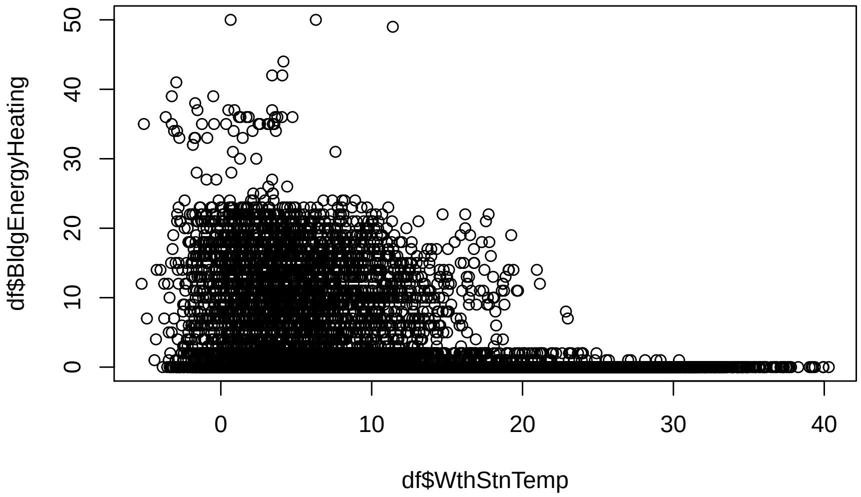
Data Visualizations

4.1 General Plots

4.1.1 Scatterplot

4.1.1.1 plot()

```r
# load data set
df <- read.csv("https://github.com/retomarek/r/raw/master/datasets/buildingMonitoringTestDataSet.

# crate simple scatterplot
plot(df$WthStnTemp, df$BldgEnergyHeating)
```

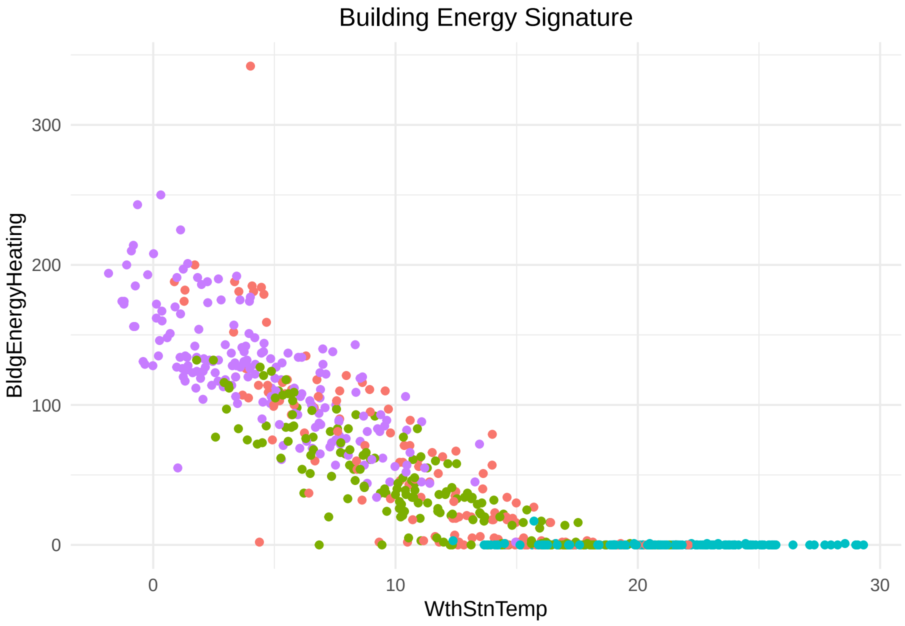


4.2 Building Energy Signature

4.2.1 static

```
library(ggplot2)
library(plotly)
library(dplyr)
library(redutils)
library(lubridate)

# load data set
df <- read.csv("https://github.com/retomarek/r/raw/master/datasets/buildingMonitoringTe
               stringsAsFactors=FALSE, sep =",")

# select data and calculate season
data <- df %>%
  select(time, WthStnTemp, BldgEnergyHeating) %>%
  mutate(season = redutils::season(df$time)) %>%
  na.omit()

# Aggregate data to daily values
data$time <- parse_date_time(data$time, "YmdHMS", tz = "Europe/Zurich")
```

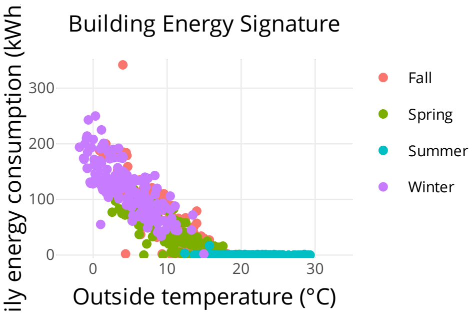
```
data$year <- as.Date(cut(data$time, breaks = "year"))
data$month <- as.Date(cut(data$time, breaks = "month"))
data$day <- as.Date(cut(data$time, breaks = "day"))

data <- data %>%
  select(day, WthStnTemp, BldgEnergyHeating, season) %>%
  group_by(day) %>%
  mutate(WthStnTemp = mean(WthStnTemp))

data <- data %>%
  group_by(day) %>%
  mutate(BldgEnergyHeating = sum(BldgEnergyHeating))

data <- data %>%
  unique()

# static chart with ggplot
p <- ggplot2::ggplot(data) +
  ggplot2::geom_point(aes(x = WthStnTemp,
                          y = BldgEnergyHeating, color=season,
                          text = paste("</br>Date:  ", as.Date(data$day),
                                       "</br>Temp: ", round(data$WthStnTemp, digits = 1), "\u00B0
                                       "</br>Energy: ", round(data$BldgEnergyHeating, digits = 0)
                                       "</br>Season: ", data$season))
                      ) +
  ggtitle("Building Energy Signature") +
        theme_minimal() +
        theme(
          legend.position="none",
          plot.title = element_text(hjust = 0.5)
        )
p
```



4.2.2 interactive

Make ggplot2 chart above interactive with plotly

```r
# continuation from upper ggplot code section
plotly::ggplotly(p, tooltip = c("text")) %>%
  layout(xaxis = list(title = "Outside temperature (\u00B0C)",
                      range = c(min(-5,min(data$WthStnTemp)), max(35,max(data$WthStnTem
         yaxis = list(title = "Daily energy consumption (kWh/d)",
                      range = c(-5, max(data$BldgEnergyHeating) + 10)),
         showlegend = TRUE
         ) %>%
  plotly::config(displayModeBar = FALSE, displaylogo = FALSE)
```


Building Energy Signature
ily energy consumption (kWh
300
200
100
0
0
10
20
30
Outside temperature (°C)
● Fall
● Spring
● Summer
● Winter

Bibliography

Grolemund, G. and Wickham, H. (2015). *Hands-on programming with R*. O'Reilly, Sebastopol, second release edition.