

Apartment Rental Prediction System

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Introduction

In this report we shall address building of an apartment rental price prediction system. The latter will be based on the ‘Apartment rental offers in Germany’ dataset available from:

<https://www.kaggle.com/corrieaar/apartment-rental-offers-in-germany>.

To reach our goal, we will use supervised machine learning techniques studied within the “*PH125.8x Data Science: Machine Learning*” course (a part of the broader HarvardX *Data Science Professional* certification program). The prediction system will be therefore based on (linear) statistical models trained on the subset of the ‘Apartment rental offers in Germany’ dataset.

The remainder of this section first present the data set, then defines the goal of this project more concretely, and finally identifies the main steps to be taken to reach the goal.

Dataset overview

As stated on the webpage of the ‘Apartment rental offers in Germany’ dataset, it contains 198332 rental offers scraped from the Germany’s biggest real estate online platform ImmobilienScout24.

The data set consists of a single CSV file: *immo_data.csv* which only contains offers for rental properties. The data features important rental property attributes, such as the living area size, the rent (both base rent as well as total rent), the location, type of energy, and etc. The **date** column present in the data set defines the time of scraping, which was done on three distinct dates: *2018-09-22*, *2019-05-10* and *2019-10-08*.

The complete list of data set columns is extensive¹ and thus in this study we will use the following subset:

```
## [1] "hasKitchen"           "heatingType"          "balcony"
## [4] "lift"                 "garden"               "cellar"
## [7] "noParkSpaces"         "livingSpace"          "typeOfFlat"
## [10] "noRooms"              "floor"                "numberOfFloors"
## [13] "condition"            "newlyConst"           "interiorQual"
## [16] "yearConstructed"      "energyEfficiencyClass" "regio1"
## [19] "regio2"                "regio3"               "baseRent"
## [22] "electricityBasePrice" "heatingCosts"          "serviceCharge"
## [25] "totalRent"             "date"
```

This sub-selection reduces the number of considered data set columns² from 48 to 26 and is motivated by the personal preferences of the report’s author and has no scientifically proven motivation. On the contrary, this column selection shall be seen as a part of problem statement. In other words, the task is to build an accurate³ rental price prediction model based on the predictors from this set of columns.

The additional data preparation steps will be described in the “*Data wrangling*” section of this document.

¹Please consider reading “*Appendix A*” for the complete list of the data set columns.

²Please consider reading “*Appendix B*” for the column descriptions.

³Please consider reading the “*Project goal*” section for an exact goal formulation.

Project goal

The goal of this project is to build a apartment rental-price prediction system for German cities. The model is to be trained and validated using the data from ‘Apartment rental offers in Germany’ dataset. The data is therefore to be split into a **modeling** and **validation** sets which will be defined in the “*Data wrangling*” section.

The system evaluation will be done using the Residual Mean Squared error (**RMSE**) which, similarly to a standard deviation, can be interpreted as: *the typical error we make when predicting a rent price*. In other words, **RMSE** will indicate an approximate amount of Euros we are on average off in our rental price predictions.

Definition: (**RMSE**)

Let r_o be the true rental price for an offer o , N_o be the number of offers, and \hat{r}_o be our prediction, then:

$$RMSE = \sqrt{\sum_{m=1}^{N_o} (r_o - \hat{r}_o)^2}$$

The definition above trivially translates into the following R function:

```
RMSE <- function(true_ratings, predicted_ratings){  
  sqrt(mean((true_ratings - predicted_ratings)^2))  
}
```

The ultimate goal of the project is to provide a statistical model, solely based on the modeling set, that on the **validation** set will be able to predict apartment rental prices with $RMSE \leq TARGET_RMSE = 50$. The way achieve that goal will be explained in the “*Modeling approach*” section of this document.

Execution plan

Let us now briefly outline the main steps to be performed to reach the previously formalized project goal:

1. **Prepare the data** – see the “*Data wrangling*” section:
 - Select, clean, and reshape relevant data; split it into training and validation sets; and etc.
2. **Analyze the dataset** – see the “*Dataset analysis*” section:
 - Perform data exploration and visualization; summarize insights on the data.
3. **Describe the modeling approach** – see the “*Modeling approach*” section:
 - Consider the insights of the data analysis; suggest the way obtain a prediction model.
4. **Present modeling results** – see the “*Modeling results*” section:
 - Train the model(s); evaluate the model(s); analyze the results.
5. **Provide concluding remarks** – see the “*Conclusions*” section:
 - Summarize the results; mention any approach limitations; outline possible future improvements.

Data wrangling

In this section we present cleaning, enriching, and restructuring the raw data taken from the ‘Apartment rental offers in Germany’ dataset.

This section will be organized as follows: First we explain how we cleaned the data and solved some of its inconsistencies, by enriching the data. Then we identify some structural changes done to the data. Further, we provide a summary of the wrangled data set. In the end, we explain how we split the entire data set into the **validation** and **modeling** sub-sets⁴.

⁴The latter will also be split into the **training** and **testing** set for the sake of model cross-validation.

Data cleaning & enriching

Let us note that the number of data entries in the original data set is equal to 198332. This data is however not ready to be worked with as it is very dirty. It contains multiple N/A values; is inconsistent – has mismatching row values, e.g. `floor = 10` and `typeOfFlat = "roof_storey"`; and has multiple outliers in numerical/integer columns.

The rest of the section is organized as follows: First, we explain cleaning of N/A values. Second, we discuss stripping of the data from the outliers. Third, we outline filtering out and correcting some of the data inconsistencies.

Removing N/A values

Consider for example the next table summarizing the number of N/A values per data set column:

## # A tibble: 26 x 3	## `Column name`	## `N/A count`	## `N/A percent`
	## <chr>	## <int>	## <dbl>
## 1	electricityBasePrice	151158	76.2
## 2	energyEfficiencyClass	143316	72.3
## 3	heatingCosts	135154	68.2
## 4	noParkSpaces	130405	65.8
## 5	interiorQual	83002	41.8
## 6	numberOfFloors	71792	36.2
## 7	condition	50318	25.4
## 8	yearConstructed	42293	21.3
## 9	floor	37612	19.0
## 10	heatingType	32605	16.4
## 11	totalRent	29762	15.0
## 12	typeOfFlat	27572	13.9
## 13	serviceCharge	5110	2.58
## 14	hasKitchen	1	0
## 15	lift	1	0
## 16	garden	1	0
## 17	cellar	1	0
## 18	livingSpace	1	0
## 19	noRooms	1	0
## 20	regio2	1	0
## 21	regio3	1	0
## 22	baseRent	1	0
## 23	date	1	0
## 24	balcony	0	0
## 25	newlyConst	0	0
## 26	regio1	0	0

As one can see, about $\frac{1}{2}$ of the columns has 2.5–80% N/A^s, whereas the other half has (almost) no N/A^s.

Cleaning the data from N/A values will be explained in the next steps:

1. We begin with the `totalRent` column as this is the value that we want to predict;
2. We proceed with the columns with the marginal (< 1%) of N/A values;
3. We cover the remaining columns in the descending order of the number of N/A values.

The first steps

The `totalRent` column contains data that we want to predict. Therefore, the rows with `totalRent == N/A` are useless to us and shall be removed. Unfortunately, this will reduce the data set by 15.01%. There are also 13 columns with a marginal (0 to 1) number of N/A values. The latter can be seamlessly removed as even if all of these N/A^s appear in different rows, we will remove at most 13 entries which is just 0.0066% of data.

The main columns

Let us consider the columns one by one. Note that, some modifications we will do to the data to remove the N/A values may introduce bias. To test that we would need a clean data set with no N/A values initially present and then to use such a data set for the trained model(s) validation. Due to the lack of time this will not be done in the case study.

Column: `electricityBasePrice` - 76.2% N/A values

We will set the electricity base price for the N/A values to zero. The motivation is that, since the number of N/A values is almost 80% and no other zero values are present:

```
x <- arog_data$selected_data %>% filter(!is.na(electricityBasePrice))
sum(x$electricityBasePrice == 0)
```

```
## [1] 0
```

it is likely that the N/A values were used to determine the fact that there is no electricity base price.

Column: `energyEfficiencyClass` - 72.3% N/A values

The energy efficiency factor levels are:

```
levels(arog_data$selected_data$energyEfficiencyClass)
```

```
## [1] "A"          "A_PLUS"     "B"          "C"
## [5] "D"          "E"          "F"          "G"
## [9] "H"          "NO_INFORMATION"
```

So we shall naturally set all the N/A energy efficiency levels to "NO_INFORMATION".

Column: `heatingCosts` - 68.2% N/A values

We will set the heating costs for the N/A values to zero as there are already 1989 zero-valued heating cost entries. It is unlikely that there are non-heated accommodations in Germany so *we assume that the 0 values, the same as N/A^s mean - “unknown”*.

Column: `noParkSpaces` - 65.8% N/A values

We will set the number of parking places for the N/A values to zero as there is already 2850 zero-valued entries. By this step we assume that, N/A is interpreted as “not applicable” or “no are available”.

Column: `interiorQual` - 38.8% N/A values

The interior quality factor levels are:

```
levels(arog_data$selected_data$interiorQual)
```

```
## [1] "luxury"      "normal"       "simple"       "sophisticated"
```

So we shall introduce a new level for the N/A values, called "unknown".

Column: numberOfFloors - 36.2% N/A values

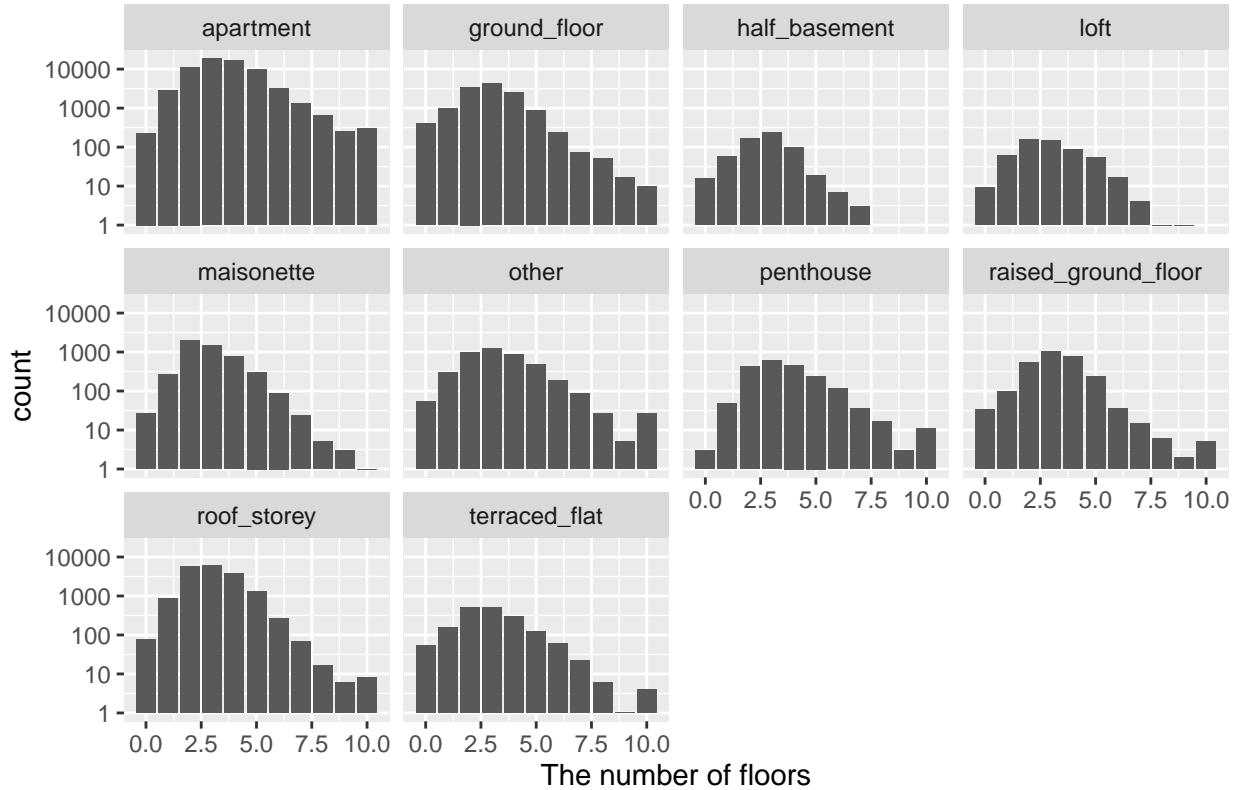
Setting the N/A values for the floors shall be agreed with the apartment type, if we gather some number of floors statistics for each available apartment type we get the following:

Table 1: Type of flat vs. number of floors statistics

typeOfFlat	numberOfFloors				
	Count	Average	Standard error	Minimum	Maximum
apartment	66844	3.9	6.6	0	999
roof_storey	18450	3.1	6.7	0	800
ground_floor	12802	3	8.9	0	999
maisonette	4979	2.9	1.5	0	43
other	4284	3.6	5	0	301
raised_ground_floor	2779	3.4	7.3	0	370
penthouse	2011	3.7	2.2	0	33
terraced_flat	1760	3	1.5	0	14
half_basement	598	2.7	1.1	0	7
loft	542	3	1.5	0	15

From where we conclude that the data we have is very polluted. Clearly, one can not expect apartments with 99 floors and alike. See also on the large average (all +/- around 3 floors) and the huge standard error values. If we visualize the results (filtering out 1662 flats with more than 10 floors), we see that:

The distribution of number of floors per flat type



the data seems to be approximately normally distributed (except for the **apartment** type) with the mean values within 2.5 - 4.0 range. This makes us believe that this data is too much biased and polluted. So we will not rely on this column in our analysis.

Column: condition - 25.4% N/A values

The condition factor levels are:

```
## [1] "first_time_use"                      "first_time_use_after_refurbishment"  
## [3] "fully_renovated"                     "mint_condition"  
## [5] "modernized"                          "need_of_renovation"  
## [7] "negotiable"                           "refurbished"  
## [9] "ripe_for_demolition"                 "well_kept"
```

So we shall introduce a new level for the N/A values, called "unknown".

Column: yearConstructed - 21.3% N/A values

There is no good default to replace the N/A values here. Yet, it is a significant amount of data which we do not want to exclude. Therefore drop this column from the analysis and just use the `newlyConst` flag column.

Column: floor - 19.0% N/A values

We could assign some `floor` values based on the flat types:

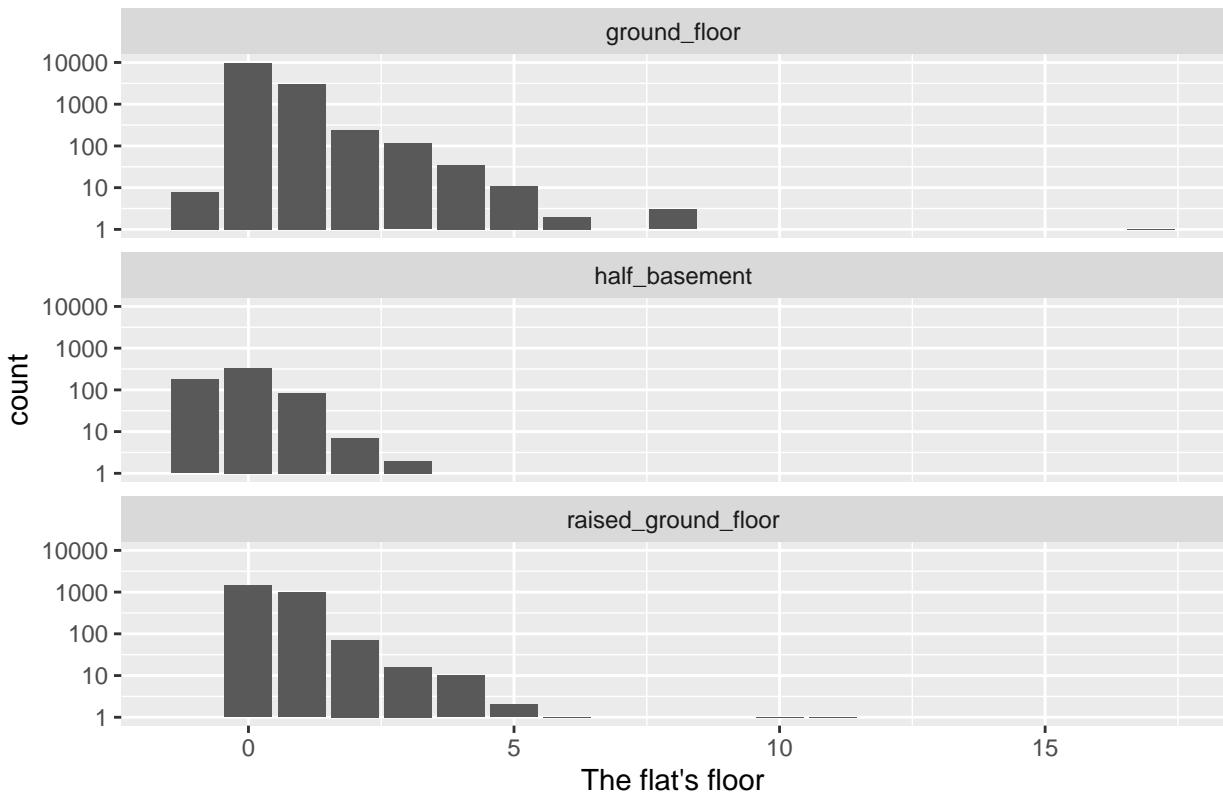
```
## [1] "apartment"              "ground_floor"          "half_basement"  
## [4] "loft"                   "maisonette"            "other"  
## [7] "penthouse"              "raised_ground_floor"  "roof_storey"  
## [10] "terraced_flat"
```

For example, we could consider assigning:

- `half_basement` – set `floor` to be the average half-basement floor value
- `ground_floor` – set `floor` = 0
- `raised_ground_floor` – set `floor` to be the average raised ground floor value

but, let us look at the floor values (filtering out 10 flats with `floor > 100`), for these flat types:

The distribution of floors per flat type



From the data above we see that we shall not only correct the N/A values but set all of the floor values for the considered flat types as follows:

- half_basement – set floor = -1
- ground_floor – set floor = 0
- raised_ground_floor – set floor = 0

If we do that then there will still be 20049 (10.1% of data) N/A floor values for the flat types for which we can not give any exact value. So we will just assign those to the mean floor value in the category.

Column: heatingType - 16.4% N/A values

The heating type factor levels are:

```
## [1] "central_heating"          "combined_heat_and_power_plant"
## [3] "district_heating"         "electric_heating"
## [5] "floor_heating"            "gas_heating"
## [7] "heat_pump"                "night_storage_heater"
## [9] "oil_heating"               "self_contained_central_heating"
## [11] "solar_heating"             "stove_heating"
## [13] "wood_pellet_heating"
```

So we shall introduce a new level for the N/A, and "H" values, called "unknown".

Column: typeOfFlat - 13.9% N/A values

The type of flat factor levels are:

```
## [1] "apartment"           "ground_floor"        "half_basement"
```

```

## [4] "loft"           "maisonette"        "other"
## [7] "penthouse"       "raised_ground_floor" "roof_storey"
## [10] "terraced_flat"

```

So we shall introduce a new level for the N/A values, called "unknown". Note that, we do not use the pre-defined level "other" here as we interpret it as known flat type which is just not on the list of available choices.

Column serviceCharge - 2.58% N/A values

We will set the service charges for the N/A values to zero. The motivation is that, there are:

```

x <- arog_data$selected_data %>% filter(!is.na(serviceCharge))
sum(x$serviceCharge == 0)

```

```

## [1] 2496

```

zero values present, so we interpret the N/A values as defining the fact of no additional service charges.

Filtering outliers

In this section we only considered the numeric/integer columns of the data set. The initial set of outliers per column is obtained using:

```

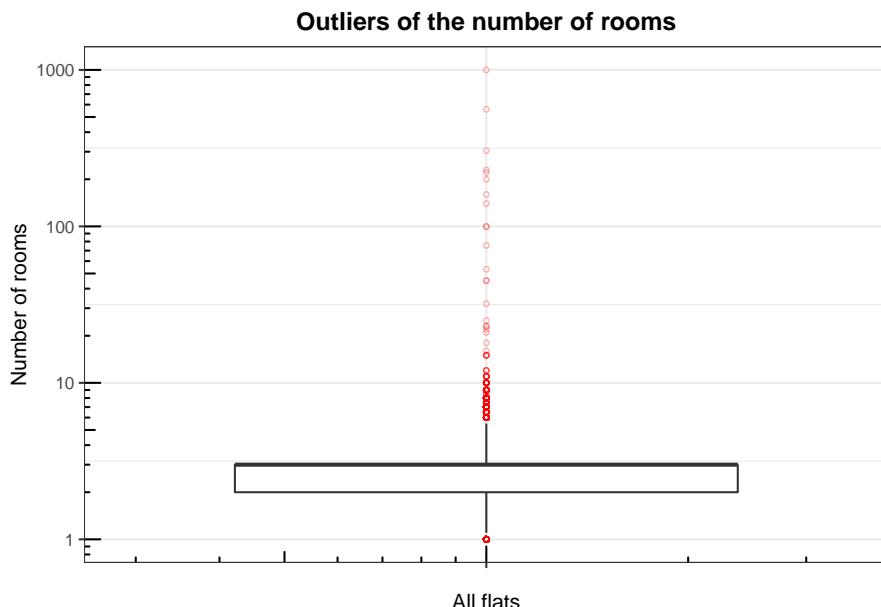
boxplot.stats(.)$out

```

However, not all of the obtained outlier values are the true outliers. It may be that some flats do stand out as examples of extraordinary property, and not due to owner input errors. This is why, for each of the column, the identified outliers are analyzed and it is then decided on how much of them is to be removed.

Column: noRooms

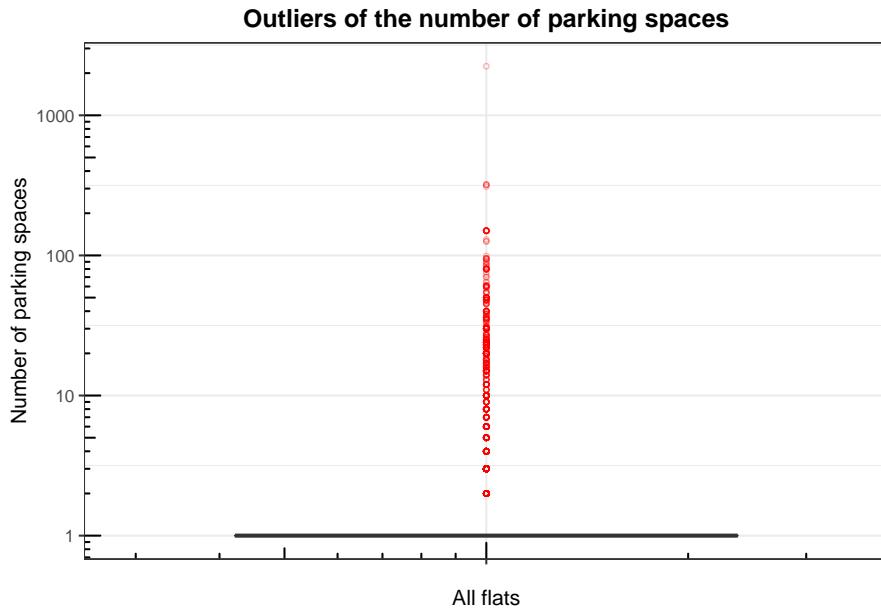
The `noRooms` column has 6038 outliers, see the plot:



We shall remove all the rows with `noRooms` outside the interval [1, 20].

Column: noParkSpaces

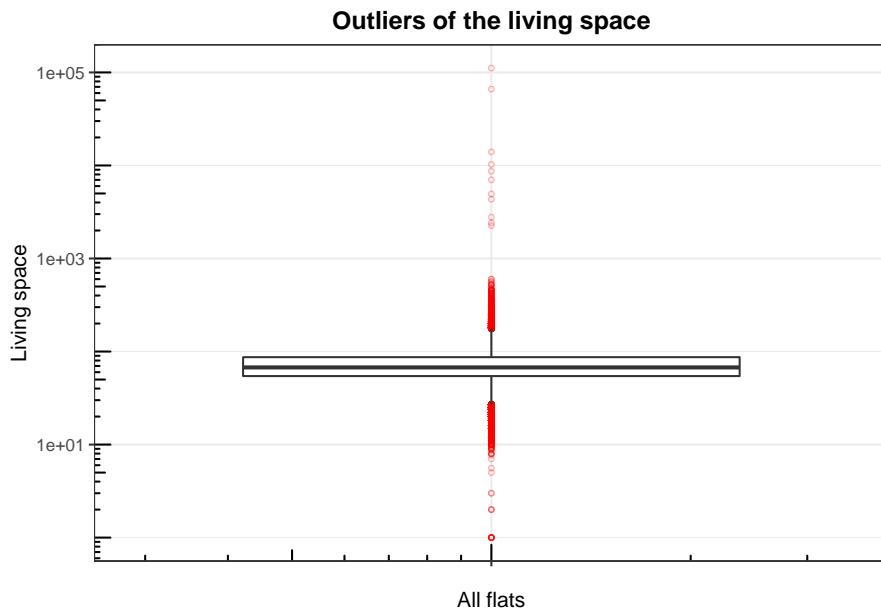
The `noParkSpaces` column has 10416 outliers, see the plot:



We shall remove all the rows with `noParkSpaces` outside the interval [0, 200].

Column: livingSpace

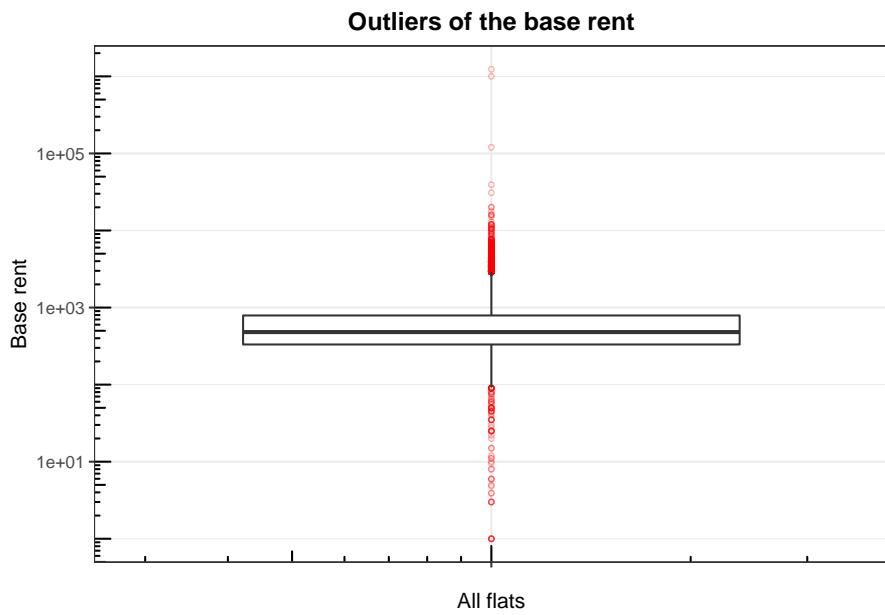
The `livingSpace` has 8830 outliers, see the plot:



We shall remove all the rows with `livingSpace` outside the interval [1, 1000].

Column: baseRent

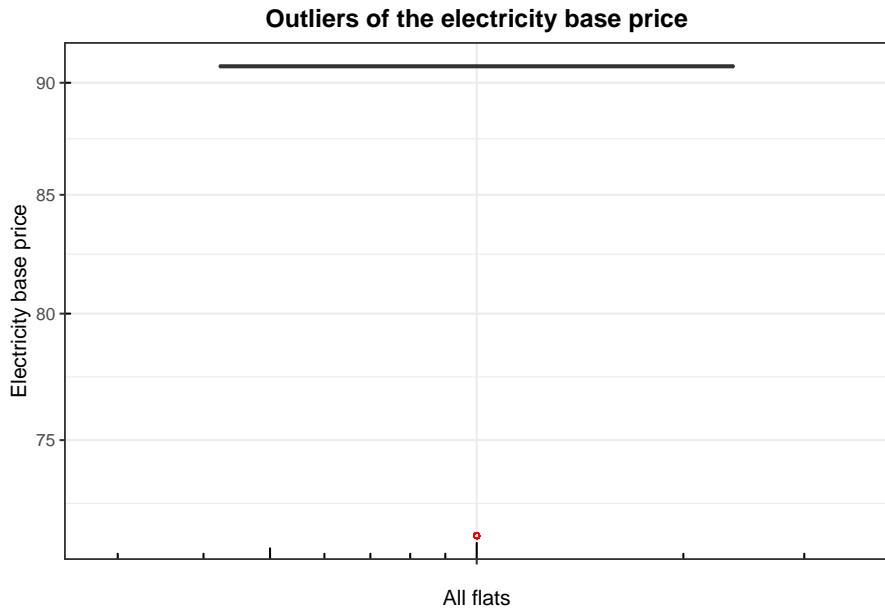
The `baseRent` has 10953 outliers, see the plot:



We shall remove all the rows with `baseRent` outside the interval $[100, 3 \times 10^4]$.

Column: `electricityBasePrice`

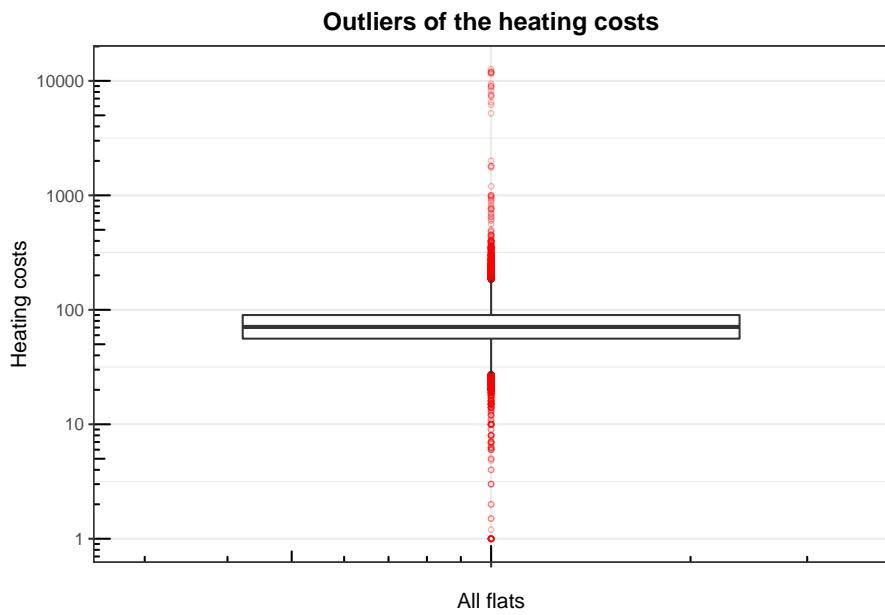
The `electricityBasePrice` has 4048 outliers, see the plot:



We shall remove all the rows with `electricityBasePrice` outside the interval $[0, 100]$.

Column: `heatingCosts`

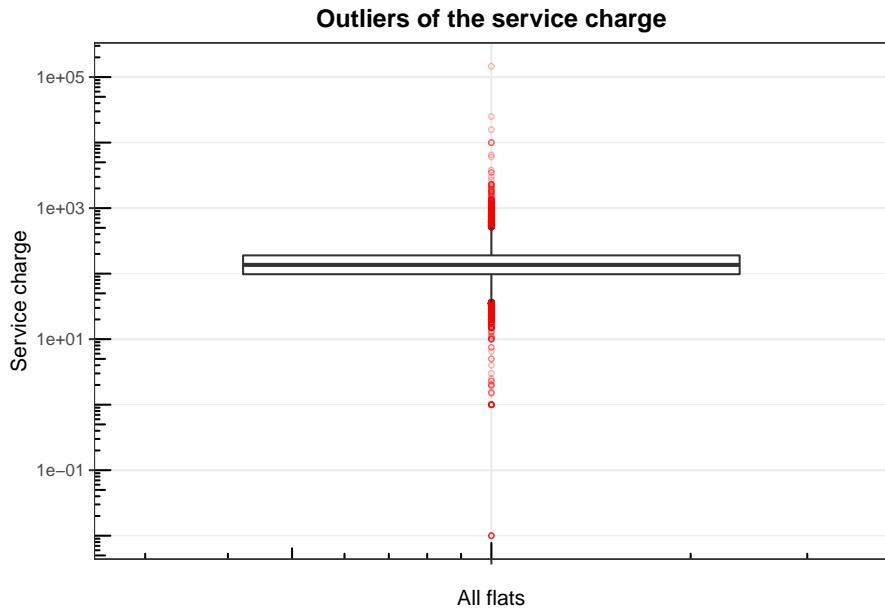
The `heatingCosts` has 4765 outliers, see the plot:



We shall remove all the rows with `heatingCosts` outside the interval [0, 3000].

Column: `serviceCharge`

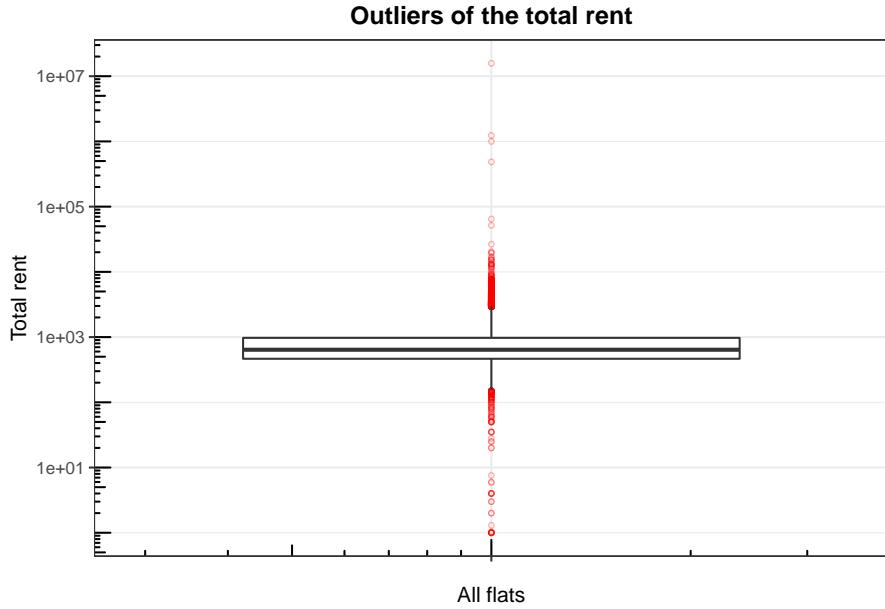
The `serviceCharge` has 6557 outliers, see the plot:



We shall remove all the rows with `serviceCharge` outside the interval [10, 10^4].

Column: `totalRent`

The `totalRent` has 9366 outliers, see the plot:



We shall remove all the rows with `totalRent` outside the interval $[10, 10^5]$.

Fixing inconsistencies

In addition to the data alterations done above we have also done the following:

- Re-setting the number of floors:
 - `half_basement_floor = -1`
 - `ground_floor_floor = 0`
 - `raised_ground_floor_floor = 0`
- Filter out flats:
 - Other than "half_basement", "other", and "unknown"; but with `floor < 0`
 - With zero `totalRent` values (207 entries)
- Fix wrong and convert scraping dates:
 - "Sep18" changes into `ymd("2018-09-22")5`
 - "May19" changes into `ymd("2019-05-10")`
 - "Oct19" changes into `ymd("2019-10-08")`
- Made sure that the integer-valued ("floor", "noParkSpaces", "noRooms") columns are rounded.

There may be more inconsistencies present in the data, for example we expect that:

```
totalRent = baseRent + electricityBasePrice + heatingCosts + serviceCharge
```

which may not be the case. Unfortunately due to the lack of time these were not analyzed further and thus may potentially influence the “accuracy” of the trained statistical model.

Restructuring data

The data set at hand does not have any complex structure. However, because we want to be able to do predictions per city and avoid cities with the same names within different lands and regions we shall combine the `regio` columns into a new single one, as follows:

⁵The `ymd()` function is provided by the `lubridate` package.

```

clean_arog_data <- clean_arog_data %>%
  unite("location", c("regio1", "regio2", "regio3"), remove=FALSE) %>%
  select(-regio1, -regio2, -regio3)

```

The resulting columns have values constructed according to the following pattern:

```
location = regio1 + "_" + regio2 + "_" + regio3
```

For example:

```
arog_data$wrangled_data$location[1:5]
```

```

## [1] Nordrhein_Westfalen_Essen_Karnap
## [2] Nordrhein_Westfalen_Steinfurt_Kreis_Emsdetten
## [3] Nordrhein_Westfalen_Bottrop_Lehmkuhle
## [4] Sachsen_Anhalt_Salzlandkreis_Schönebeck_Elbe
## [5] Sachsen_Chemnitz_Bernsdorf
## 8087 Levels: Baden_Württemberg_Alb_Donau_Kreis_Allmendingen ...

```

In addition we have rounded and turned into integer columns all the integer-valued columns of the data set:

```
c("floor", "noParkSpaces", "noRooms")
```

```
## [1] "floor"      "noParkSpaces" "noRooms"
```

Wrangled data set

Let us now summarize the resulting clean data:

```

## # A tibble: 22 x 3
##   `Column name`     `N/A count` `N/A percent`
##   <chr>              <int>          <dbl>
## 1 hasKitchen          0             0
## 2 heatingType          0             0
## 3 balcony              0             0
## 4 lift                  0             0
## 5 garden                0             0
## 6 cellar                0             0
## 7 noParkSpaces          0             0
## 8 livingSpace           0             0
## 9 typeOfFlat            0             0
## 10 noRooms               0             0
## 11 floor                 0             0
## 12 condition              0             0
## 13 newlyConst             0             0
## 14 interiorQual            0             0
## 15 energyEfficiencyClass    0             0
## 16 location                0             0
## 17 baseRent                 0             0
## 18 electricityBasePrice       0             0
## 19 heatingCosts              0             0
## 20 serviceCharge             0             0
## 21 totalRent                 0             0
## 22 date                     0             0

```

As one can notice, the dat set size has been reduced from 198332 to 162742. The major reason for that is excluding the rows with the N/A values of the `totalRent` column. Let us recall that the number of such raws

was 15.01% of the data set, e.g. 29770 rows. It now remains to notice that $198332 - 29770 = 168562 > 162742$. The remaining delta of 5820 rows ($\approx 2.9\%$ of data) is explained by cleaning the `floor/typeOfFlat` columns, filtering-out outliers, and etc.

The data has been cleaned but we can expect that there is some noise in the data which we have not addressed. We might get more data-quality insights when we perform data analysis in the subsequent sections.

Splitting data

To facilitate supervised learning, the wrangled data is split into the `modeling`, 90% of data, and `validation`, 10% of data, sets. The former will be used for training statistical model(s) and the latter for the model(s) validation. Note that, for the sake of subsequent cross validation during modeling part, we further split the `modeling` set into the `training`, 80% thereof, and `testing`, 20% thereof, sets.

We split the data in the following steps:

1. The data is randomly split into two parts according to the specified ratio:

```
test_index <- createDataPartition(y = data_set$totalRent, times = 1,
                                  p = ratio, list = FALSE)
```

2. The `test_index` rows are the candidates for the `testing/validation` set rows
3. The factorized column values of the `testing/validation` set are considered:

```
str_data <- capture.output(str(arog_data$wrangled_data))
str_replace_all(str_subset(str_data, "Factor"), "levels.*","levels ...")

## [1] " $ heatingType           : Factor w/ 14 levels ...
## [2] " $ typeOfFlat          : Factor w/ 11 levels ...
## [3] " $ condition            : Factor w/ 11 levels ...
## [4] " $ interiorQual        : Factor w/ 5 levels ...
## [5] " $ energyEfficiencyClass: Factor w/ 10 levels ...
## [6] " $ location              : Factor w/ 8087 levels ..."
```

4. The rows with the values not present in the `testing/modeling` set are dropped
5. The `testing/modeling` set consists of rows absent in the `testing/validation` set

The procedure above ensures that the `testing/validation` set can always be evaluated on a model trained on the `testing/modeling` set. For more details, see the `create_arog_data` and `split_train_test_sets` functions located in the `apartment_rental_project.R` script.

The resulting set sizes are as follows:

- `modeling` – 146660 rows, 90.1% of data
 - `training` – 117820 rows, 80.3% of `modeling` set
 - `testing` – 28840 rows, 19.7% of `modeling` set
- `validation` – 16082 rows, 9.9% of data

As expected, due to returning `testing/validation` set rows to the `testing/modeling` set for consistency, the desired set ratios are biased. The `validation` set size is almost as prescribed (10% of data), but the `testing` set size is affected more significantly⁶. Yet, we see no issue as the `testing` set is still $> 10\%$ of the `modeling` set, which should be enough for performing cross validation.

⁶The requested `testing` set size was 20% of the `modeling` set.

Data analysis

In this section we shall use data visualization and other techniques to investigate the properties of the data we could use to build the prediction model. In the remainder of the section we shall address:

1. Possible **timing** effects
2. Possible **location** effects
3. Predictor's correlation
4. Principle component analysis

Eventually, we shall conclude the section with a short summary of our findings.

Possible **timing** effects

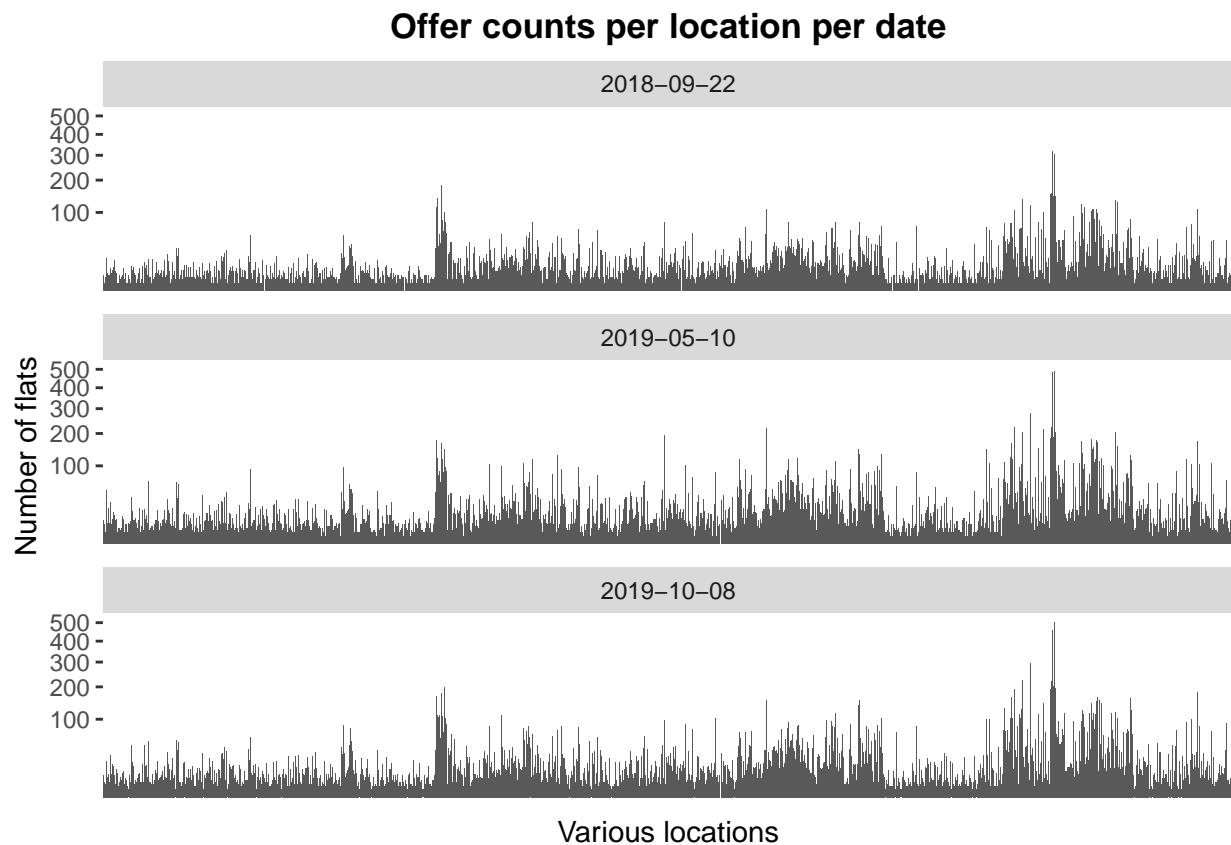
Let us consider any possible effects introduced by the scraping date. In essence, the goal of this section is to understand whether:

1. We shall keep the data scraped on different date distinct, and have the `date` column as a predictor, or
2. We could consider the combined statistics for all the data ignoring the `date` field as a predictor

We answer this question based on the analysis of “Flat offers per date”, “Flat counts per location per date”, and “Average totalRent per date”

Flat offers per date

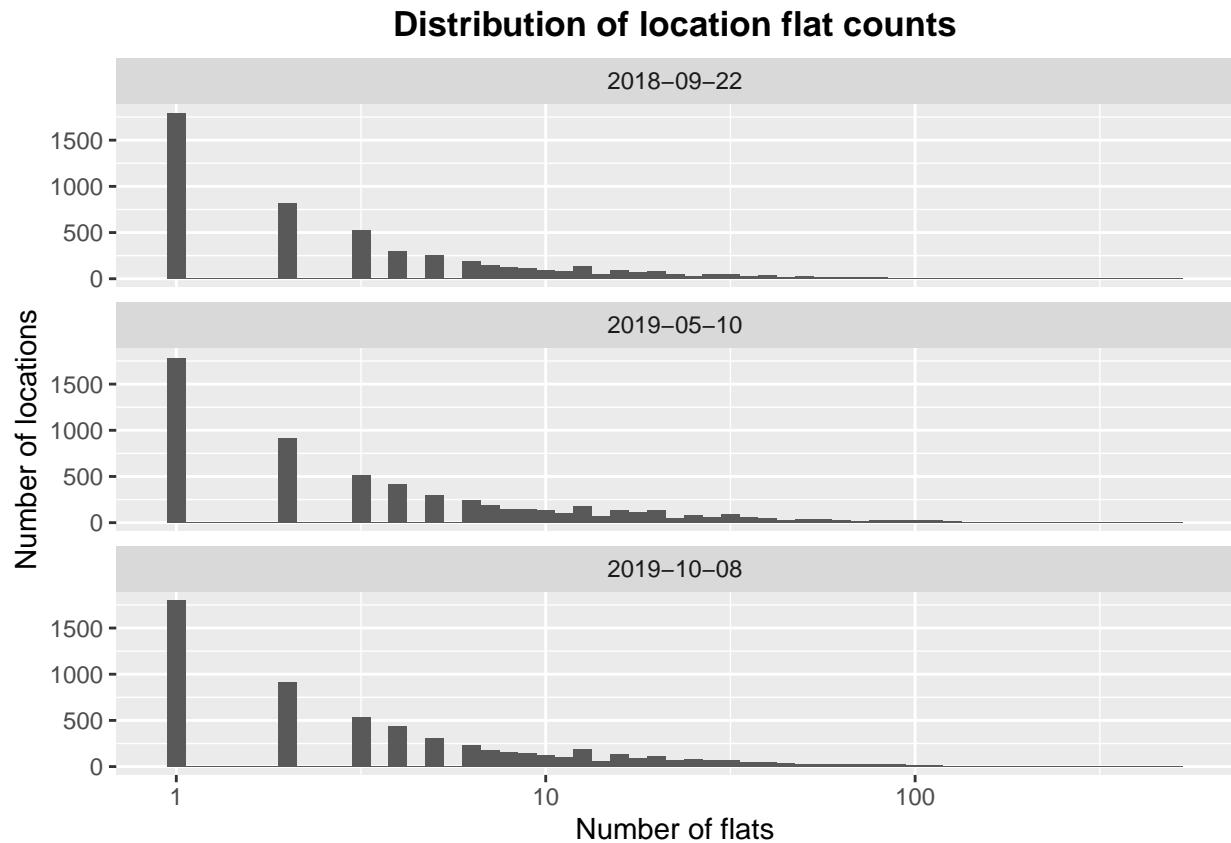
Let us consider the number of flat offers per location per data scraping date:



The number of flats listed by location seems to follow the same pattern on all of the three data scraping dates. It seems like we may ignore the `date` column and consider the joint statistics. To have more solid grounds for that, let us investigate the flat counts per location per `date`.

Flat counts per location per date

The distribution of flat counts per location indicates that there are a lot of locations with just one flat. However, there are also a few locations with a “large” (> 100) number of flat offers.



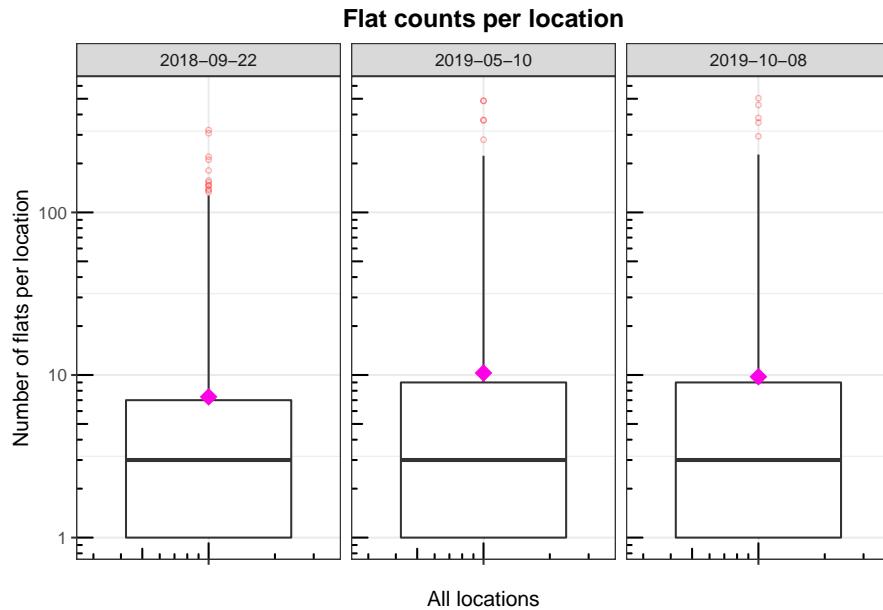
The median numbers of flats per location are equal for all the dates:

```
## # A tibble: 3 x 2
##   date      median
##   <date>     <dbl>
## 1 2018-09-22     3
## 2 2019-05-10     3
## 3 2019-10-08     3
```

The average numbers of flats per location for the last two scrapes are equal, and for the first one is somewhat smaller:

```
## # A tibble: 3 x 2
##   date      average
##   <date>     <dbl>
## 1 2018-09-22     7
## 2 2019-05-10    10
## 3 2019-10-08    10
```

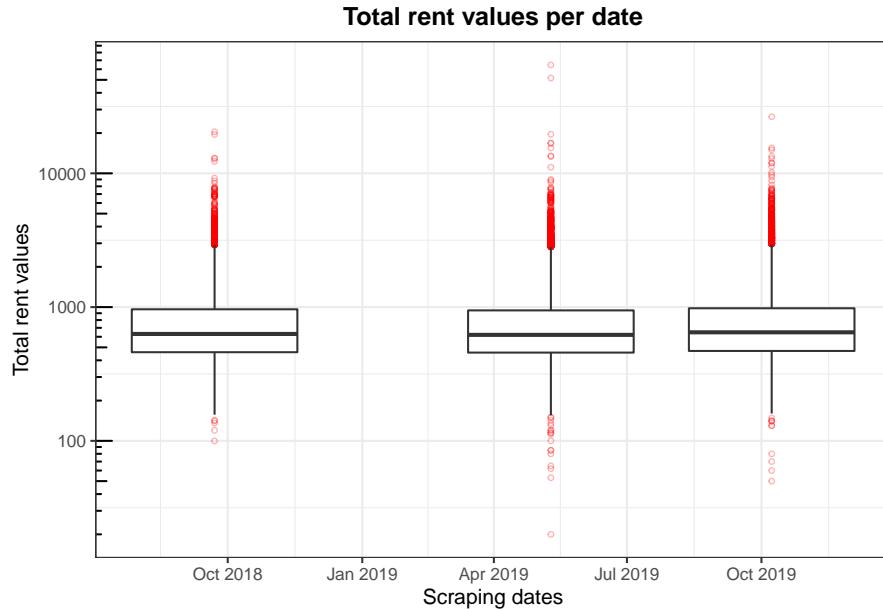
Overall, the number of flats per location seems to be stable from one date to another:



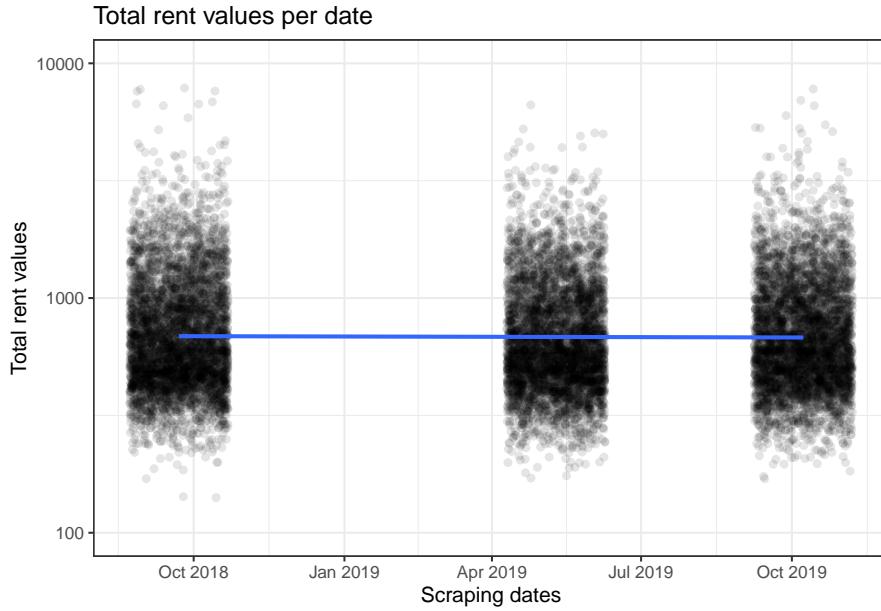
It seems like we may ignore the `date` column and consider the joint statistics. To have more solid grounds for that, let us investigate the average `totalRent` per date.

Average `totalRent` per date

Let us plot the `totalRent` per date:



As we see the data seems to be distributed similarly, moreover the does not seem to be any trend in average `totalRent` per date, as computed with `geom_smooth(method="lm")`:



There does not seem to be any global⁷ timing effect in `totalRent` related to the scraping date. Please note that in the plot above, for better visualization, we took a 5000 sub-sample of the data and limited the y axis range by $[100, 10^4]$. The latter did not influence the "lm" computed trend.

Conclusion: We can ignore the `date` column and consider the joint statistics for all the dates.

Possible location effects

Let us consider any possible effects introduced by the location. In essence, the goal of this section is to understand whether:

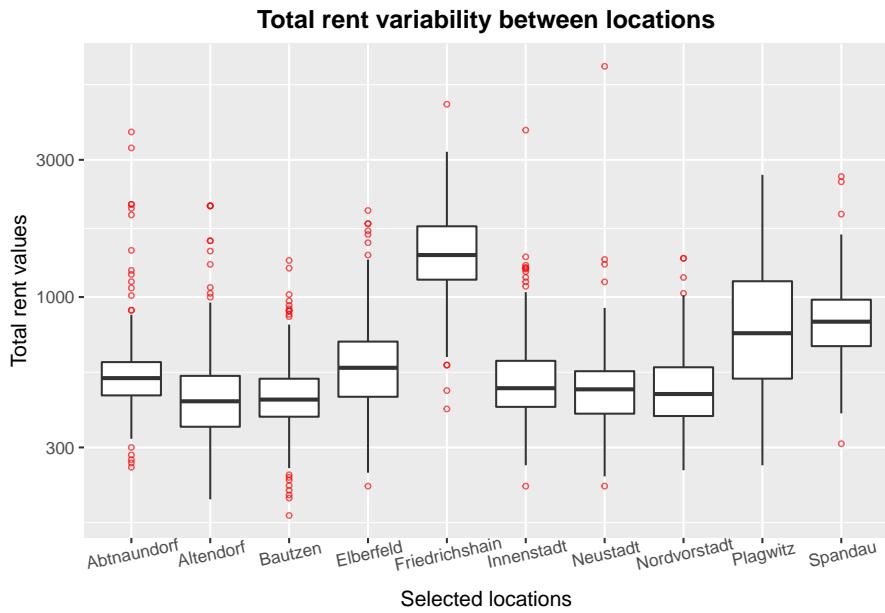
1. The `totalRent` values are location dependent
 - Suggests using the `location` column as a predictor
2. The offered flat counts per location:
 1. Have influence on the number of `totalRent` value outliers
 - Suggests using Regularization in statistical modeling
 2. Are correlated with the `totalRent` values
 - Facilitates using the `location` column as a predictor

We answer this question based on the analysis of “Average `totalRent` per location”, “Min/Max `totalRent` per location flat count”, and “Average `totalRent` per location flat count”.

Average `totalRent` per location

Let us consider the variability of the `totalRent`, for several randomly chosen locations, with > 100 offers:

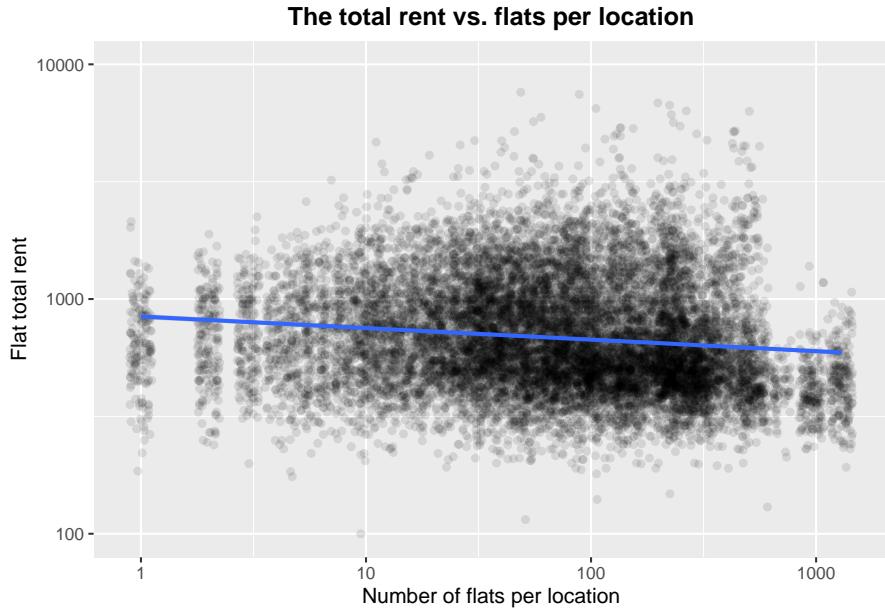
⁷There may be some location specific timing effects, but we do not consider them due to the lack of time.



Conclusion: Locations differ quite significantly in their `totalRent` – this is a **location effect**.

Average `totalRent` per location flat count

Let us plot the `totalRent` per location flat count, ordered by the count. Also to show the trend we will use `ggplot` with `geom_smooth(method = 'gam')`.



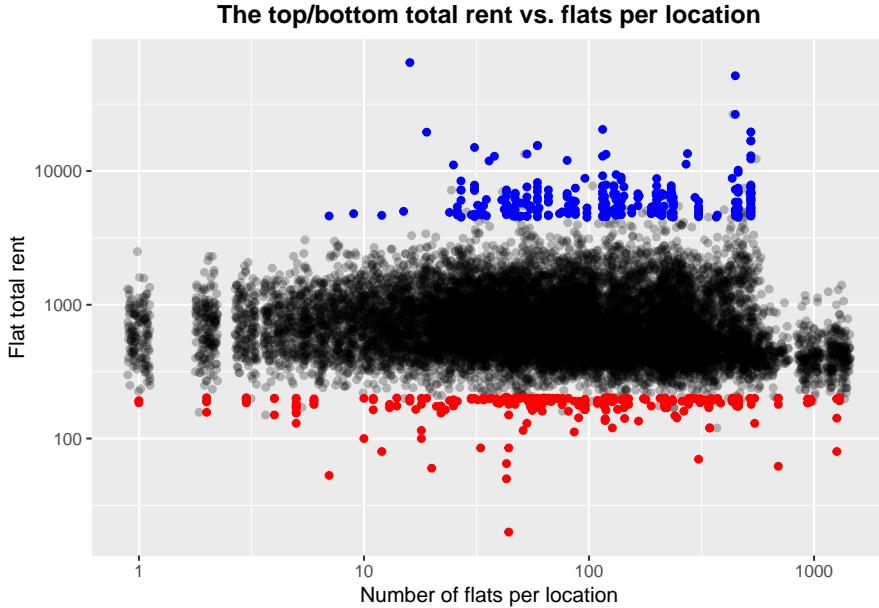
Please note that in the plot above, for better visualization, we took a 1.5×10^4 sub-sample of the data and limited the y axis range by $[100, 10^4]$. The latter did not influence the "gam" computed trend.

Conclusion: There is a trend in that the places with more flat offers have on-average lower `totalRent` values - this is a **number of offers effect**.

Min/Max totalRent per location flat count

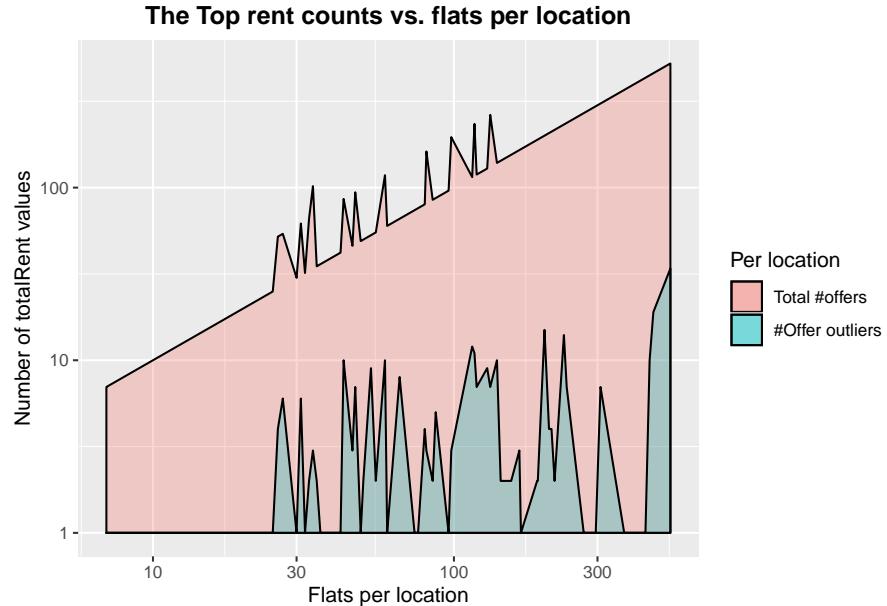
Let us the maximum and minimum `totalRent` values relative to the flat count per location. In other words, each `location` has a number of flats offered. If we now combine the flat offers per location into a single totally ordered *flat-offers range*, we can plot how many locations there are with that many orders. Or we can plot the `totalRent` values offered in locations with the same number of flats. The latter will help us to see if the extreme `totalRent` values, like 300 `top` and 300 `bottom` priced flats are more likely to be encountered in locations with lower or larger number of flat offers.

If we indicate `top` and `bottom` priced flats on the plot then we can observe:

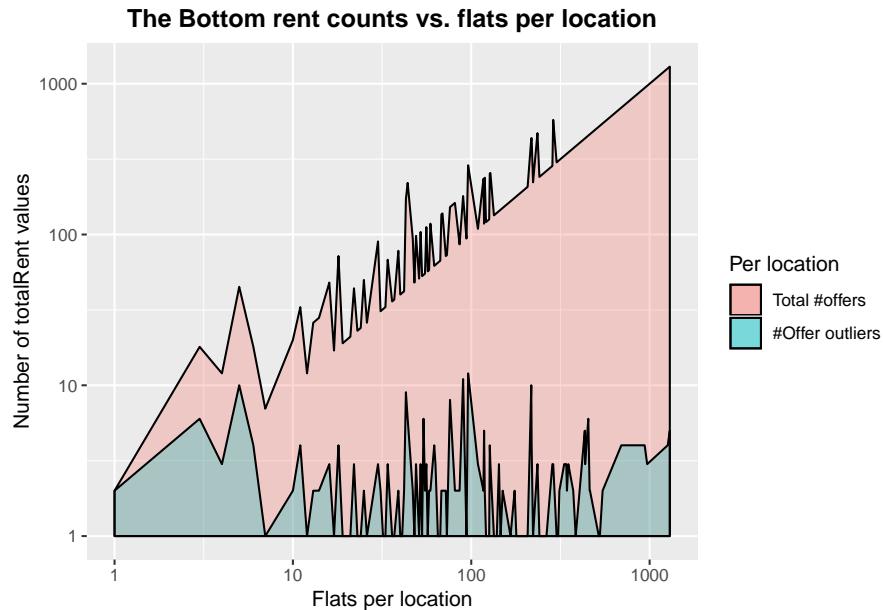


that it seems that[12^] the `top/bottom` priced rentals are, almost uniformly, spread all over the *flat-offers range*. [^12]: Please note that in this plot, for better visualization, we took a 1.5×10^4 sub-sample of the data.

To get a better view on data, considering `top` and total `totalRent` counts versus the *flat-offers range*:

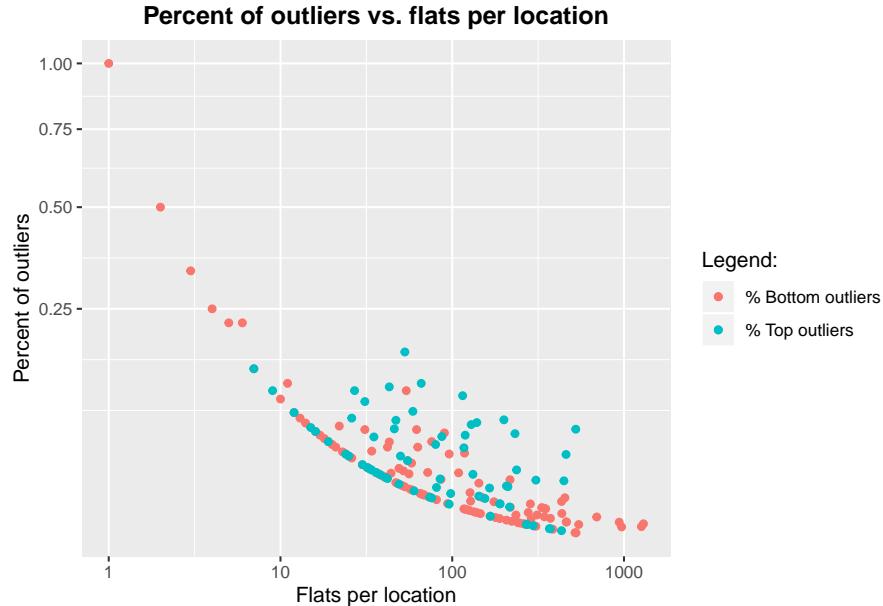


Considering bottom and total totalRent counts versus the flat-offers range:



The total count is computed as the sum of offers in the locations with the same number of offers. Effectively it is equal to "number of offers in location" \times "number of locations with this number of offers". This explains almost line-like behavior of the "Total #offers" plots. The irregularities are caused by having more than one location with the given number of flat offers (mind the \log_{10} scale of the x and y axis).

The number of bottom outliers is \approx uniform across the flat-offers range. The number of top outliers looks somewhat biased to be larger for locations with more offers. Let us plot the outliers to total ratio:



The plot above has, even though contains quite some “noise” for 50-200 flats per location, indicates the common trend of having proportionally less outliers in locations with more rental offers.

Conclusion 1: It is less likely to have a cheap rentals in locations with large number of offers. **Conclusion 2:** It is less likely to have an expensive rentals in locations with a larger number of offers.

Predictor's correlation

In this case-study we have selected 21 potential predictors:

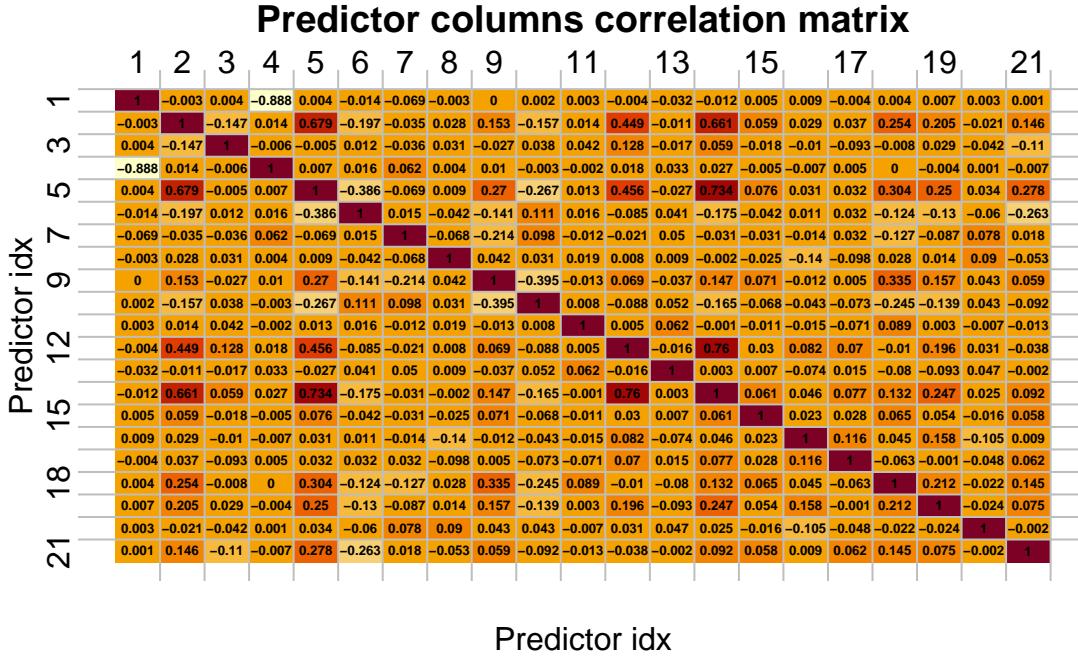
```
## [1] "hasKitchen"           "heatingType"          "balcony"
## [4] "lift"                 "garden"               "cellar"
## [7] "noParkSpaces"         "livingSpace"          "typeOfFlat"
## [10] "noRooms"              "floor"                "condition"
## [13] "newlyConst"            "interiorQual"         "energyEfficiencyClass"
## [16] "location"              "baseRent"              "electricityBasePrice"
## [19] "heatingCosts"          "serviceCharge"        "date"
```

As we have discussed in the `timing` effects section the `date` column seems to be eligible for exclusion. However, to give this a more formal ground and also to reduce the number of predictors even further let us consider the correlation matrix of the training data columns:

```
#First create the predictors matrix, from the wrangled data
predictors_mtx <- arog_data$wrangled_data %>%
  select(-totalRent) %>%
  data.matrix()

#Next compute the correlations matrix and round off the values
corr_mtx <- predictors_mtx %>%
  cor(.) %>% round(., 3)
```

When visualized, we see that there is quite a few predictors with strong correlation:



For instance, `heatingType` (idx: 2) is strongly correlated with `garden` (idx: 5), `typeOfFlat` (idx: 9), `condition` (idx: 12), `interiorQual` (idx: 14), `electricityBasePrice` (idx: 18), and `date` (idx: 21).

Having highly correlated columns implies that we could use less predictors to build a statistical model without loosing much accuracy.

Principle Component Analysis

As motivated by the correlation analysis above, here we will use the Principle Component Analysis (PCA) to see if we have a distance preserving transformation of our data that gives us a new feature-space basis in which most of the data variability is explained by fewer predictors:

```
#Run the PCA analysis
pca_result <- prcomp(predictors_mtx)
#Report the summary
summary(pca_result)

## Importance of components:
##                               PC1        PC2        PC3        PC4        PC5        PC6
## Standard deviation    2101.8878 459.05602 148.70605 68.76676 41.45316 19.46240
## Proportion of Variance 0.9485   0.04524  0.00475  0.00102  0.00037  0.00008
## Cumulative Proportion 0.9485   0.99371  0.99846  0.99947  0.99984  0.99992
##                               PC7        PC8        PC9        PC10       PC11       PC12       PC13       PC14       PC15
## Standard deviation    16.96046 4.49 3.968 3.475 3.463 2.446 2.242 1.343 0.6259
## Proportion of Variance 0.00006 0.00 0.000 0.000 0.000 0.000 0.000 0.000 0.0000
## Cumulative Proportion 0.99998 1.00 1.000 1.000 1.000 1.000 1.000 1.000 1.0000
##                               PC16      PC17      PC18      PC19      PC20      PC21
## Standard deviation    0.502 0.4409 0.4353 0.3871 0.3665 0.2265
## Proportion of Variance 0.000 0.0000 0.0000 0.0000 0.0000 0.0000
## Cumulative Proportion 1.000 1.0000 1.0000 1.0000 1.0000 1.0000
```

As one can see from the PCA summary above, according to Cumulative Proportion of Variance, it shall suffice to use the first two principle components (PC1, and PC2) to explain $\approx 99.3\%$ of the data.

Data analysis summary

In the “*Data analysis*” section we have analyzed our data with respect to possible **timing**, and **location** effects. In addition, to reduce the number of predictors we’ve performed predictor’s correlation and principle component analysis. The findings of this section can be summarized as follows.

Data effects:

In case we are to build our own statistical model, as opposed using one of the already available via the **cared** package of R, we should:

1. The **timing** effect is not confirmed:
 - We can ignore the **date** column and consider the joint statistics for all the dates.
2. The **location** effects are confirmed:
 - The strong correlation of **location** with **totalRent** has to be taken into account⁸

Dimension reduction:

Due to a high correlation of multiple predictors we can significantly reduce the dimensionality of the feature space. It suffices to use the first two/six principle components to explain $\approx 99.3/99.99\%$ of the data.

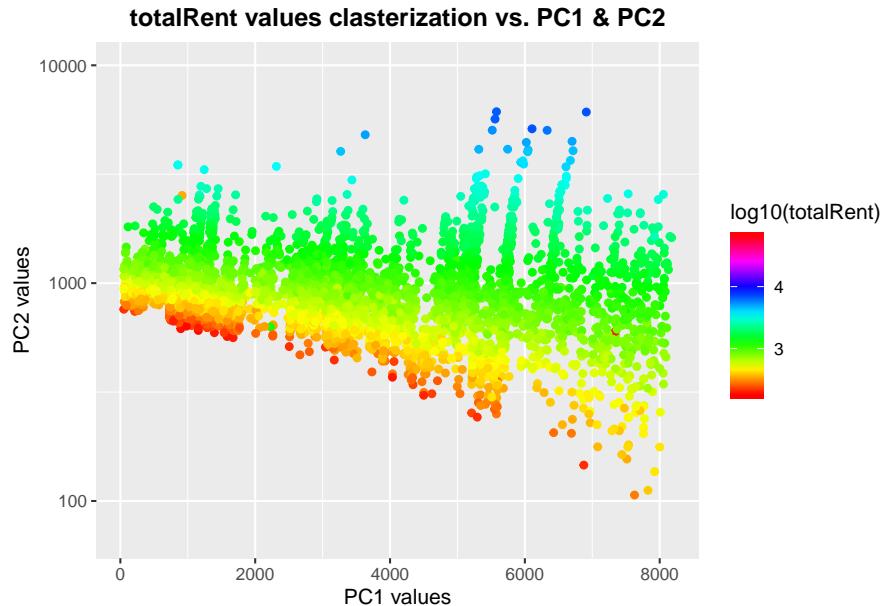
⁸This includes the discovered correlation from the **flat counts** per location as the flat offers per location do not very much with time.

Modeling approach

To begin, let us recall the project's goal and one important data observation gained:

- **Goal:** Build a prediction model for the `totalRent` values with an RMSE score ≤ 50 ;
- **Data:** About 99.3% data variability is in the first two principle components;

Let us make a scatter plot of PC1 vs PC2 indicating the corresponding `totalRent` values with color:



Here, for better visualization, we:

- Take a 5000 sub-sample of data;
- Limit the PC2 range by $[70, 10^4]$;
- Linearly shift both PC1 and PC2 to the positive half-space;
- Use \log_{10} scale for both PC1 and PC2;

From the plot above, there is a clear clasterization of the `totalRent` values. However, its structure is intricate and is not likely to be captured, with desired accuracy, with a simple (linear) regression models. Thus, instead of creating a new Bayesian model, we shall attempt using the existing ones that can be trained via the `caret` package of R. Given that the `totalRent` column is numeric, we will consider the following models⁹:

- "`lm`" – Linear Regression
- "`glm`" – Generalized Linear Model
- "`knn`" – k-Nearest Neighbor Classification
- "`Rborist`" – Random Forest¹⁰
- "`svmLinear`" – Support Vector Machines with Linear Kernel
- "`gamLoess`" – Generalized Additive Model using LOESS

The algorithms above will be run with the default parameters, unless tuning grid parameters are required. Therefore we will consider the entire `modeling` set, as any cross-validation will be done within the `train(.)` method of the `caret` package. Last but not least, we will only use the first two principle components of the available predictors data. Any models that will fail to be trained within (`TRAIN_CPU_TIME_OUT_SECONDS = 1.08×10^4`) CPU seconds will be discarded from the further use. Any additional model training parameters, if required, will be presented in the “*Modeling results*” section of this report.

⁹For more information see also the list of caret's Available Models.

¹⁰This is a high-performance implementation of a random forest model "`rf`"

Modeling code snippets

Disclaimer: This section is EXCLUSIVELY meant for the readers interested in implementation details!

To further clarify our approach, below we provide some of the code used for model training and evaluation. First, we present the main utility functions. Next, we show their use in a single *model-train-evaluate* sequence.

As for PCA, we convert our data into a numerical-data matrix, here we apply:

```
#-----
# This function prepares predictors data matrix from a given data set.
#   data_set -- the data set to prepare the data matrix from
# The performed steps are:
#   1. Remove the totalRent column
#   2. Converting to numeric (data) matrix
# The resulting matrix is returned "as-is"
#-----

prepare_data_matrix <- function(data_set) {
  #Compute the full matrix from the data set
  data_mtx <- data_set %>% select(-totalRent) %>% data.matrix()

  #Return the predictors matrix
  return(data_mtx)
}
```

To get the selected PC predictors matrix from the numerical-data matrix we employ:

```
#-----
# This function takes:
#   pca_result - the PCA analysis results
#   data_mtx - the data matrix
#   num_pc - the number of PC to consider, defaults to NUM_PC_TO_CONSIDER
# and transforms the data_mtx into the PC matrix by:
#   1. Zero-centering the data_mtx columns
#   2. Applying pca_result$rotation matrix
#   3. Selecting num_pc first columns
# The resulting matrix is returned "as-is"
#-----

prepare_pc_predictors <- function(pca_result, data_mtx, num_pc = NUM_PC_TO_CONSIDER) {
  #Zero-center the columns
  cent_pred_mtx <- sweep(data_mtx, 2, colMeans(data_mtx))

  #Rotate to move to the new basis
  rot_pred_mtx <- cent_pred_mtx %*% pca_result$rotation

  #Only return the required principle component columns
  return(rot_pred_mtx[,1:num_pc])
}
```

With the functions above, we can prepare the numerical modeling and validation set data matrixes for the totalRent values plus the first two principle components (PC1 and PC2) using:

```
#-----
# This function takes the modeling and validation sets to prepare the
# data that will be used for model training and validation in the PC
# (principle component) space. The function arguments are:
#   model_set - the modeling set
```

```

#      valid_set - the validation set
# The result is a list with the following attributes:
#      model_pc_mtx - the matrix with R (totalRent), PC1, PC2
#                      columns for the modeling set
#      valid_pc_mtx - the matrix with R (totalRent), PC1, PC2
#                      columns for the modeling set
#-----
prepare_pc_space_data <- function(model_set, valid_set) {
  #Compute the data matrixes for the data sets
  model_mtx <- prepare_data_matrix(model_set)
  valid_mtx <- prepare_data_matrix(valid_set)

  #Perform the PCA analysis on the modeling matrix
  pca_result <- prcomp(model_mtx)

  #Prepare the PC space matrix for the modeling set
  pc_mtx_col_names <- c("R", "PC1", "PC2")
  model_pc_mtx <- prepare_pc_predictors(pca_result, model_mtx)
  model_pc_mtx <- cbind(model_set$totalRent, model_pc_mtx)
  colnames(model_pc_mtx) <- pc_mtx_col_names

  #Prepare the PC space matrix for the validation set
  valid_pc_mtx <- prepare_pc_predictors(pca_result, valid_mtx)
  valid_pc_mtx <- cbind(valid_set$totalRent, valid_pc_mtx)
  colnames(valid_pc_mtx) <- pc_mtx_col_names

  #Remove the temporary data
  rm(pca_result, model_mtx, valid_mtx)

  #Return the required data
  return(list(model_pc_mtx = model_pc_mtx,
             valid_pc_mtx = valid_pc_mtx))
}

```

The model training is then to be done with:

```

#-----
# This function allows to train a model specified by the method
#      model_pc_mtx - the numeric-valued predictor space data matrix
#      method - the method to be used
# The training will be done with a time-out defined by the
#      GLOBAL_METHOD_TIME_OUT_SECONDS
# The result is the list with the following elements:
#      method - the method used
#      start_time - the time the training started
#      success - the success indicating flag
#      end_time - the time the training finished, if success == TRUE
#      fit_model - the fit model, if success == TRUE
#-----
train_model <- function(model_pc_mtx, method, ...) {
  #Remove the fit model global if it exists
  ifrm(fit_model)

  #Initialize new empty training results list

```

```

train_res <- list(method = method)

#Train the model, with a time-out
tryCatch({
  train_res <- withTimeout({
    #Record the start time
    train_res <- append(train_res, list(start_time = Sys.time()))

    #Fit the model from data
    fit_model <- train(model_pc_mtx[,2:ncol(model_pc_mtx)],
                        model_pc_mtx[,1], method = method, ...)

    #Record the end time and the result
    train_res <- append(train_res, list(fit_model = fit_model))
  }, timeout = TRAIN_CPU_TIME_OUT_SECONDS)
}, TimeoutException = function(ex) {
  message("Timeout (", TRAIN_CPU_TIME_OUT_SECONDS,
         " sec.) while training the '", method, "' model, skipping!")
})

#Mark the success flag
train_res <- append(train_res,
                     list(end_time = Sys.time(),
                          success = !is.null(train_res$fit_model)))

#Remove the fit model global if it exists
ifrm(fit_model)

#Return the result
return(train_res)
}

```

The model validation then can be performed by using:

```

#-----
# The model evaluation function takes the:
#   train_res - the model training results with the fit model to make predictions
#   valid_pc_mtx - the validation set data matrix in PC space
# Once the model predicts the values are the RMSE score is computed.
# The result of the function is the list with the following elements:
#   exp_res - the expected result values, i.e. valid_pc_mtx[,1]
#   act_res - the actually predicted values
#   rmse    - the RMSE score between valid_pc_mtx[,1] and act_res
#-----

evaluate_model <- function(train_res, valid_pc_mtx) {
  if(train_res$success) {
    #Predict the raw data based on the fit model and predictors
    act_res <- predict(train_res$fit_model,
                        valid_pc_mtx[,2:ncol(valid_pc_mtx)],
                        type = "raw")
    #Compute the RMSE score
    rmse <- RMSE(act_res, valid_pc_mtx[,1])
  } else {
    #Training failed so return the NA results
  }
}

```

```

    act_res <- NA
    rmse     <- NA
}

#Create the resulting list and return
return(list(exp_res = valid_pc_mtx[, 1],
           act_res = act_res, rmse = rmse))
}

```

With the functions above the complete *model-train-evaluate* sequence for a KNN look as follows:

```

#Prepare PC space data
pc_space_data <- prepare_pc_space_data(
  arog_data$modeling_data, arog_data$validation_data)

#Train and validate the KNN model
knn_train_res <- train_model(pc_space_data$model_pc_mtx, "knn",
                             tuneGrid = data.frame(k = KNN_K_SEQUENCE))
knn_mdl_res <- evaluate_model(knn_train_res, pc_space_data$valid_pc_mtx)
knn_mdl_res$rmse

```

For more details, see the supplied `apartment_rental_project.R` modeling script.

Modeling results

Below, we shall present our experimental results. First, we describe the hardware they were obtained on. Next, we present the training and validation results for each individual model. Finally, we provide a brief summary of our findings.

Used hardware

The experiments were run on the following hardware at hand:

```

Model Name: MacBook Pro
Model Identifier: MacBookPro11,4
Processor Name: Intel Core i7
Processor Speed: 2,2 GHz
Number of Processors: 1
Total Number of Cores: 4
L2 Cache (per Core): 256 KB
L3 Cache: 6 MB
Memory: 16 GB
Boot ROM Version: 194.0.0.0.0
SMC Version (system): 2.29f24

```

Modeling results

Let us consider the training and validation results per model.

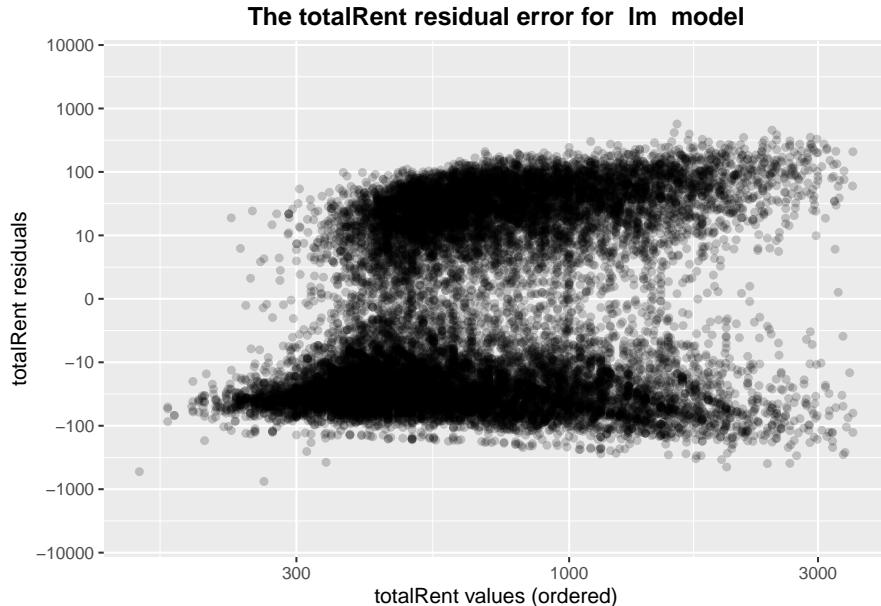
Please note that in this section when plotting the residual values, for the sake of better visualization, we will always take a 2×10^4 sub-sample of the data, and limit the `totalRent` axis (x) range by [150, 3500], and the `residuals` axis (y) range by [-5000, 5000]. These settings do not influence the overall picture.

Linear Regression – lm

Consider the summary of the trained lm model:

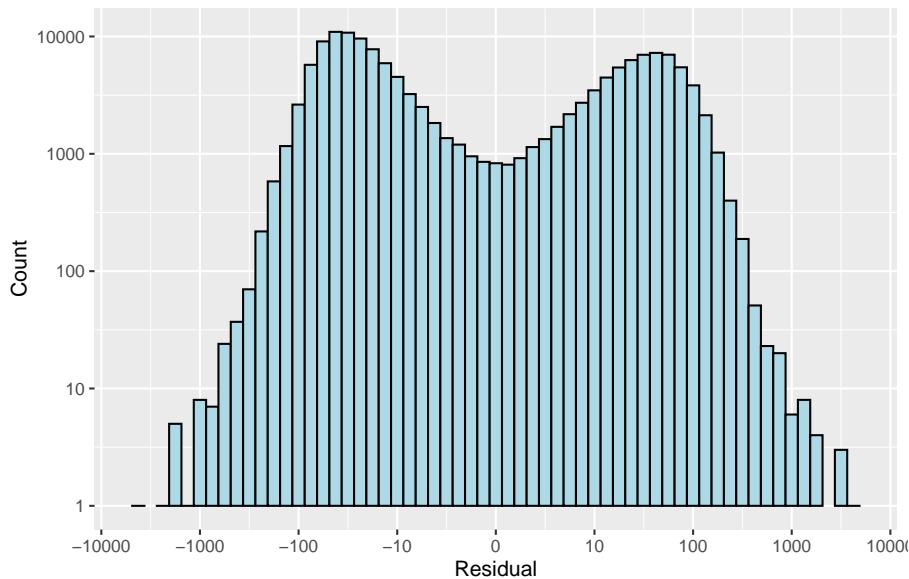
```
##  
## Call:  
## lm(formula = .outcome ~ ., data = dat)  
##  
## Residuals:  
##      Min       1Q   Median       3Q      Max  
## -19882     -31      -6      25  64000  
##  
## Coefficients:  
##             Estimate Std. Error t value Pr(>|t|)  
## (Intercept) 8.012e+02  6.180e-01 1296.4 <2e-16 ***  
## PC1         1.049e-01  2.938e-04   357.1 <2e-16 ***  
## PC2         1.110e+00  1.342e-03   826.9 <2e-16 ***  
## ---  
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1  
##  
## Residual standard error: 236.7 on 146657 degrees of freedom  
## Multiple R-squared:  0.8469, Adjusted R-squared:  0.8469  
## F-statistic: 4.056e+05 on 2 and 146657 DF,  p-value: < 2.2e-16
```

The residuals are spread rather symmetrically around the zero indicating a good model fit:



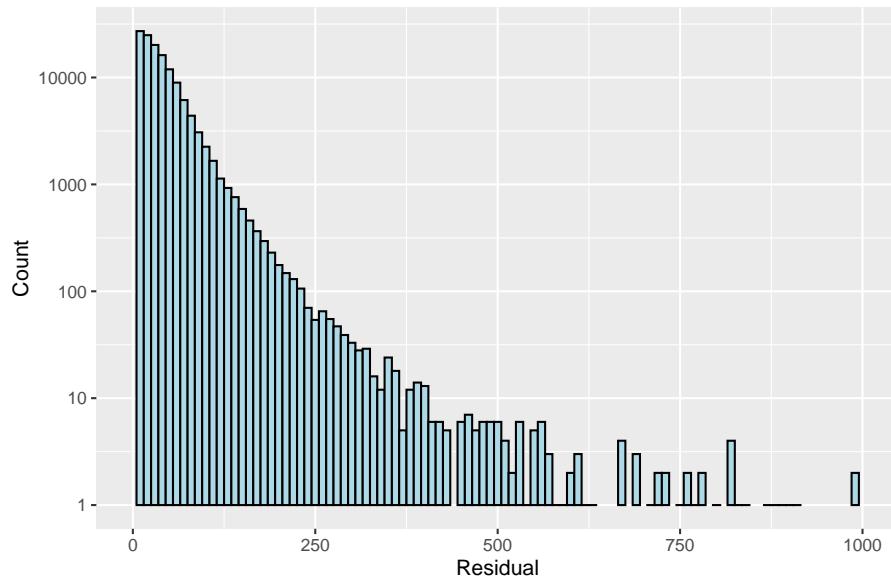
The histogram of the residual values looks as follows:

The totalRent residual error distribution for Im model



The absolute residual values are then distributed as follows:

The abs(residual) distribution for Im model



Note that, the mean absolute residual value is 40.13 and the standard deviation is 233.26.

According to the Residual Standard Error, the actual `totalRent` can deviate from the regression plane by ≈ 237 , on average. In other words, given that the intercept (average `totalRent`) is ≈ 801 Euro, we can say that the percentage error is (any prediction would still be off by) 29.5%.

The R-squared (R^2) statistic value of 0.8469 suggests that about 84.6% of the `totalRent` variance is indeed explained by the predictor variables (PC1, and PC2).

The large F-statistic value of $4.056e + 05$, even given the large number of data points, also indicates a strong relation between the predictor and response (`totalRent`) variables.

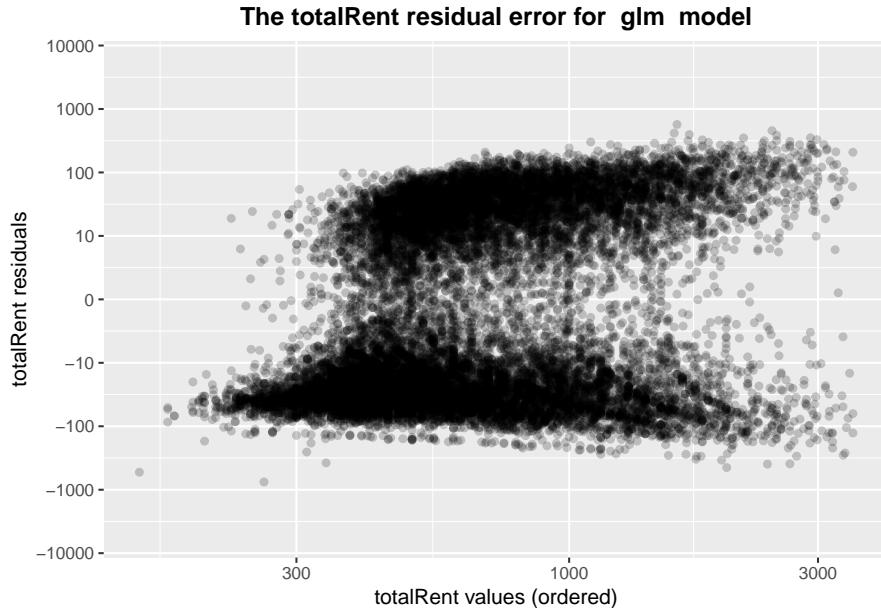
The RMSE computed on the `validation` set is 62, and it took just 5 seconds to train this model.

Generalized Linear Model – `glm`

Consider the summary of the trained `glm` model:

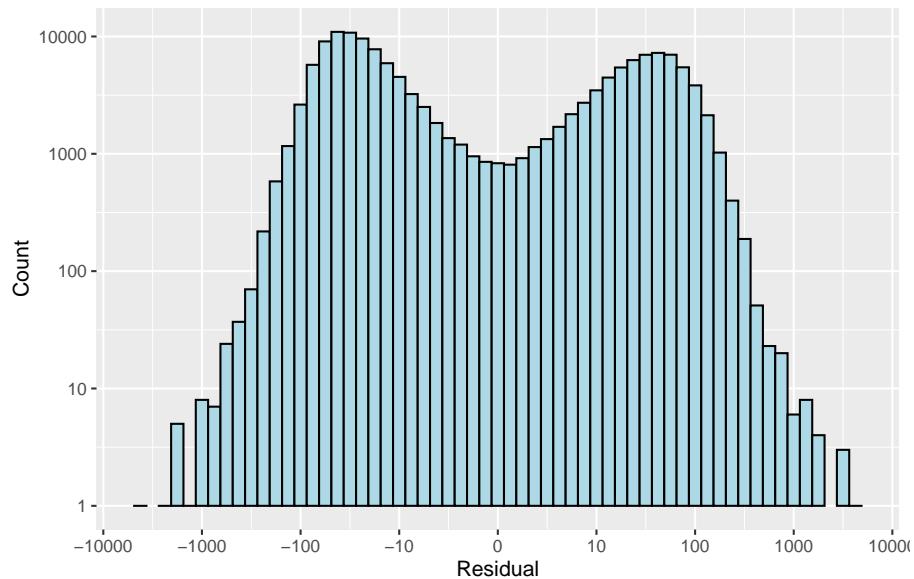
```
##  
## Call:  
## NULL  
##  
## Deviance Residuals:  
##      Min       1Q   Median       3Q      Max  
## -19882     -31      -6      25    64000  
##  
## Coefficients:  
##             Estimate Std. Error t value Pr(>|t|)  
## (Intercept) 8.012e+02 6.180e-01 1296.4 <2e-16 ***  
## PC1         1.049e-01 2.938e-04   357.1 <2e-16 ***  
## PC2         1.110e+00 1.342e-03   826.9 <2e-16 ***  
## ---  
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1  
##  
## (Dispersion parameter for gaussian family taken to be 56020.66)  
##  
## Null deviance: 5.3663e+10 on 146659 degrees of freedom  
## Residual deviance: 8.2158e+09 on 146657 degrees of freedom  
## AIC: 2019712  
##  
## Number of Fisher Scoring iterations: 2
```

The residuals are spread rather symmetrically around the zero indicating a good model fit:



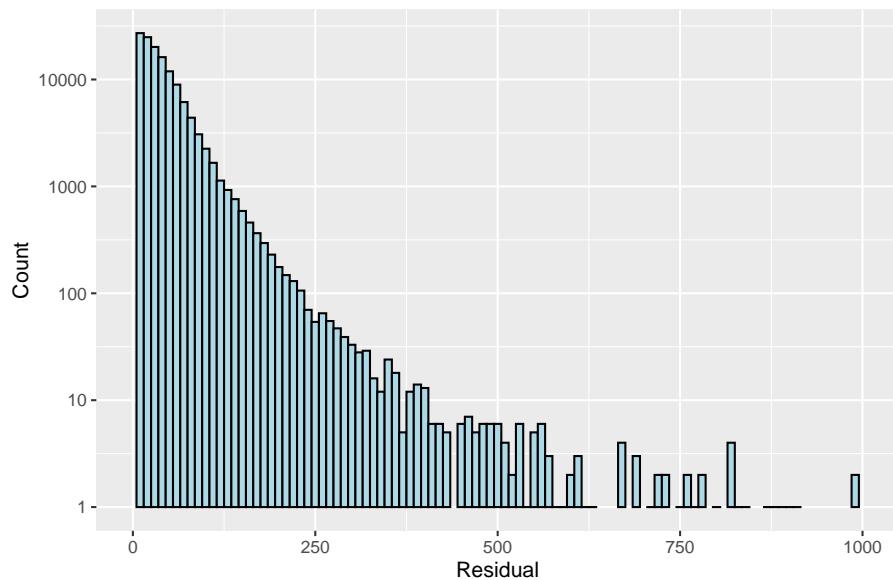
The histogram of the residual values looks as follows:

The totalRent residual error distribution for glm model



The absolute residual values are then distributed as follows:

The abs(residual) distribution for glm model



Note that, the mean absolute residual value is 40.13 and the standard deviation is 233.26.

The one “order of magnitude difference” between the Null and Residual deviances however indicates a significant effect of the predictors on the model accuracy.

The RMSE computed on the validation set is 62, and it took just 9 seconds to train this model.

K-Nearest Neighbors – knn

Consider the summary of the trained knn model:

```
##          Length Class      Mode
## learn        2    -none-   list
## k            1    -none- numeric
```

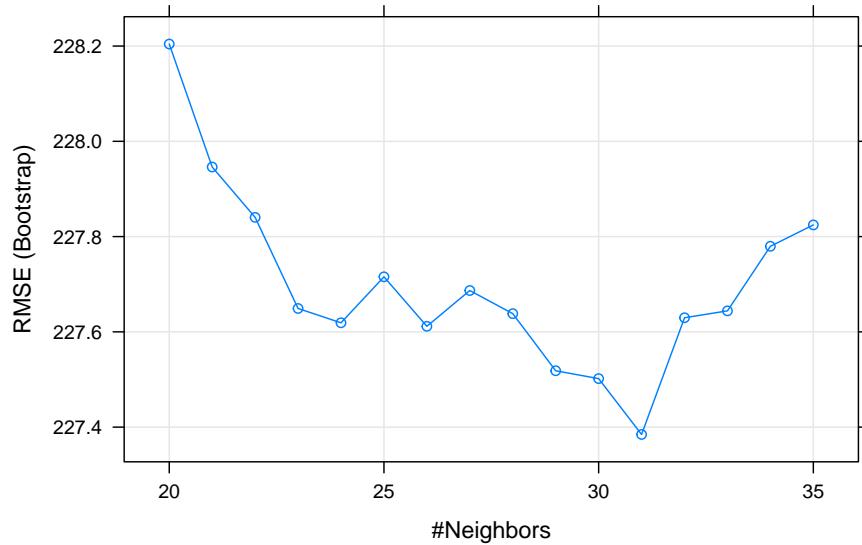
```

## theDots      0      -none-    list
## xNames       2      -none-    character
## problemType 1      -none-    character
## tuneValue    1      data.frame list
## obsLevels   1      -none-    logical
## param        0      -none-    list

```

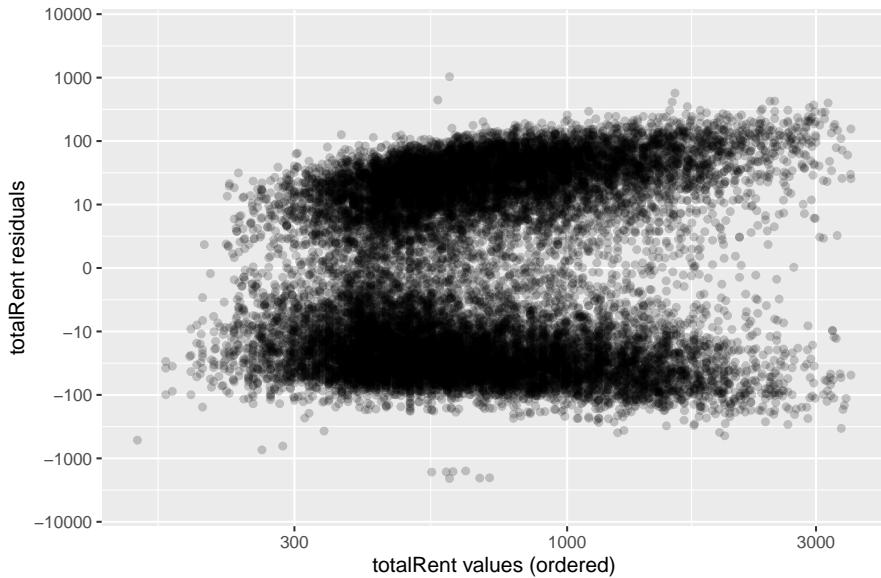
This is the first and only model that we trained with the tuning grid parameters defined:

Tuning grid KNN performance

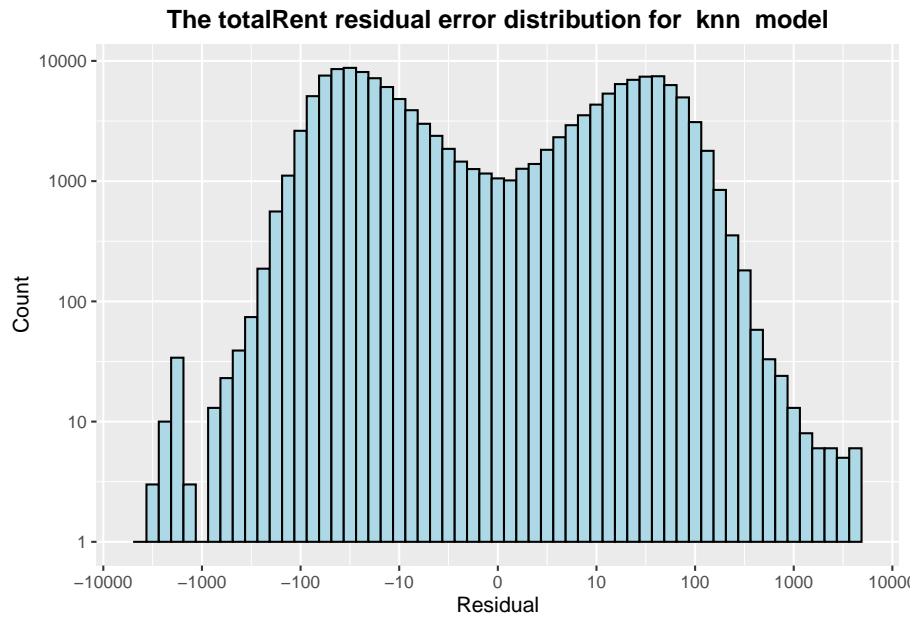


The residuals are spread rather symmetrically around the zero indicating a good model fit:

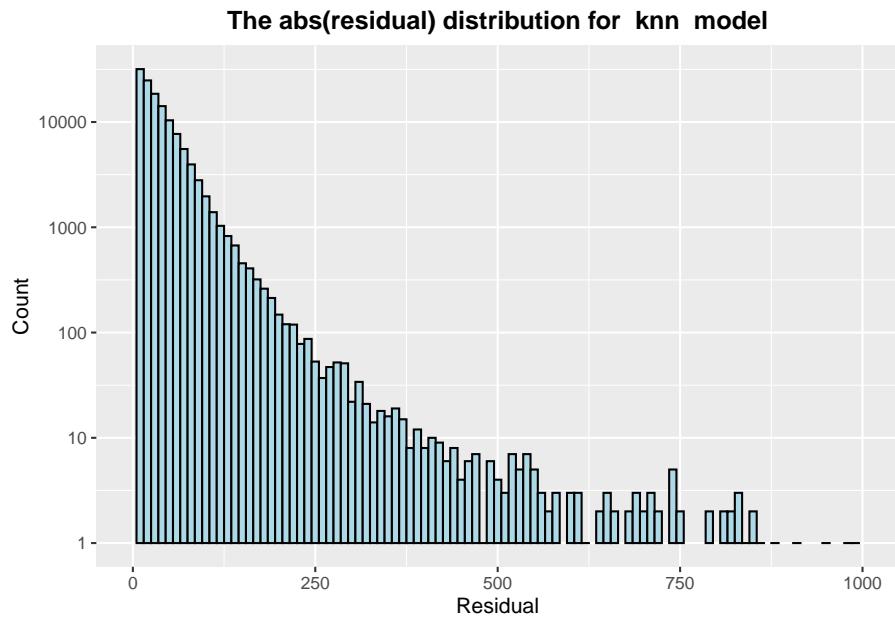
The totalRent residual error for knn model



The histogram of the residual values looks as follows:



The absolute residual values are then distributed as follows:



Note that, the mean absolute residual value is 37.72 and the standard deviation is 231.01.

The RMSE computed on the validation set is 73.8, and it took 1.0556×10^4 seconds to train this model.

Random Forest – Rborist

Consider the summary of the trained Rborist model:

```
##          Length Class      Mode
## bag         4    -none-   list
## forest      4     Forest   list
## leaf        5    LeafReg  list
## signature   4   Signature list
## training    4    -none-   list
```

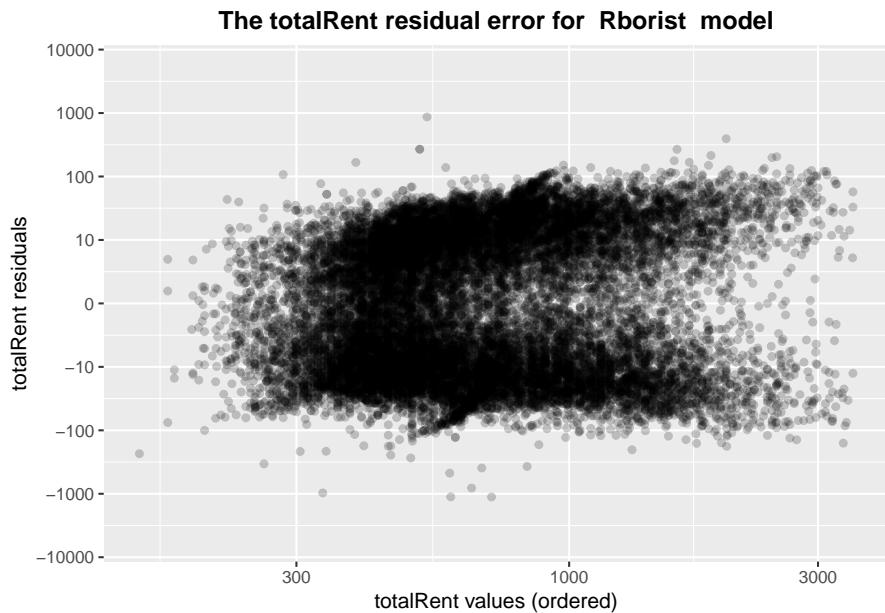
```

## validation 6      ValidReg   list
## xNames     2      -none-     character
## problemType 1    -none-     character
## tuneValue   2      data.frame list
## obsLevels  1      -none-     logical
## param      0      -none-     list

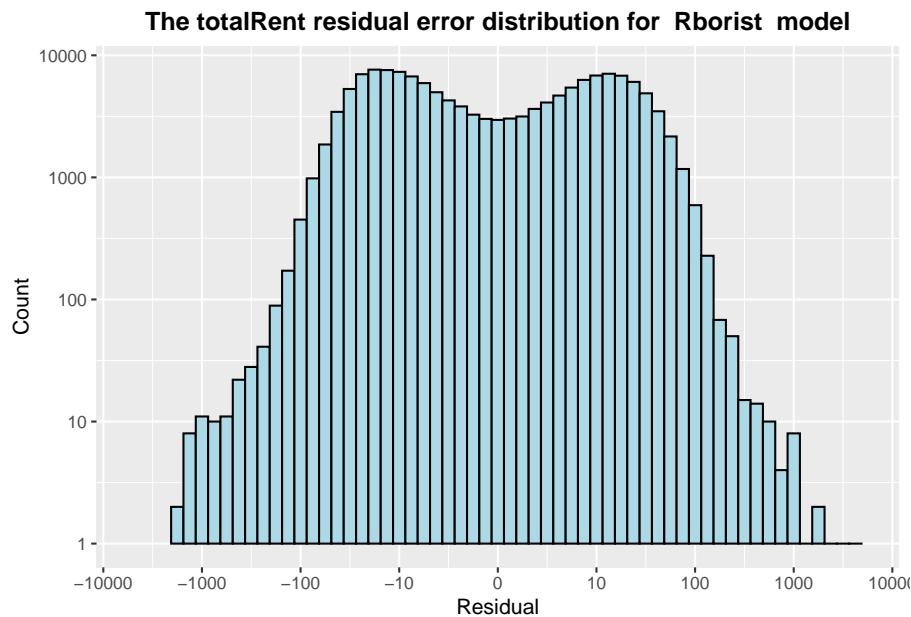
```

Even though it is possible, we did not specify the tuning grid parameters for this method.

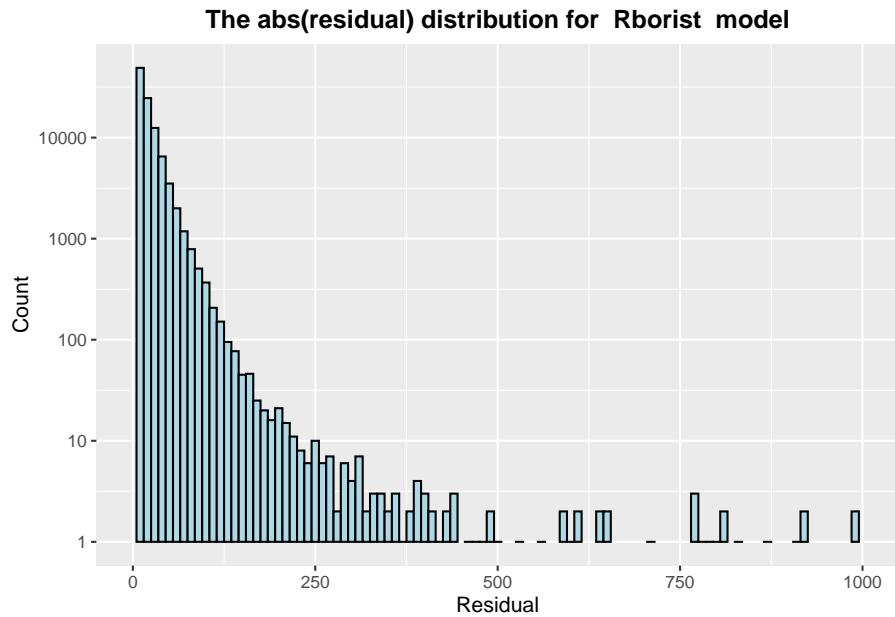
The residuals are spread rather symmetrically around the zero indicating a good model fit:



The histogram of the residual values looks as follows:



The absolute residual values are then distributed as follows:



Note that, the mean absolute residual value is 16.7 and the standard deviation is 102.27.

The RMSE computed on the validation set is 70.5, and it took 2543 seconds to train this model.

Support Vector Machines – `svmLinear`

Consider the summary of the trained `svmLinear` model:

```
## Length Class Mode
##      1  ksvm     S4
```

This summary does not contain much insightful information. Moreover, the `resid(.)` method fails on the fit model with the message:

```
svm_resid <- resid(svm_fit)

## Error: $ operator not defined for this S4 class
```

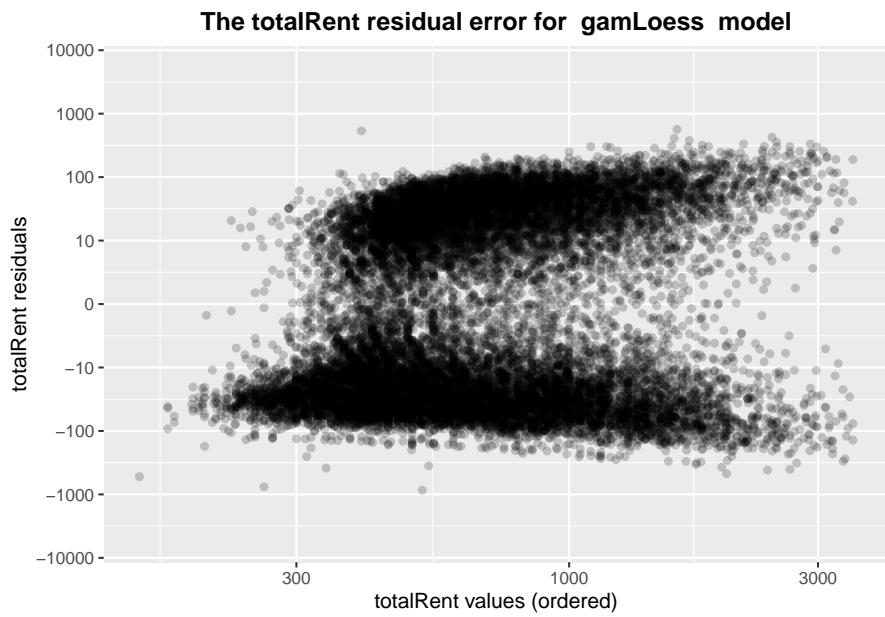
Therefore the analysis of the residuals for this model will be skipped.

The RMSE computed on the validation set is 61.94, and it took 7030 seconds to train this model.

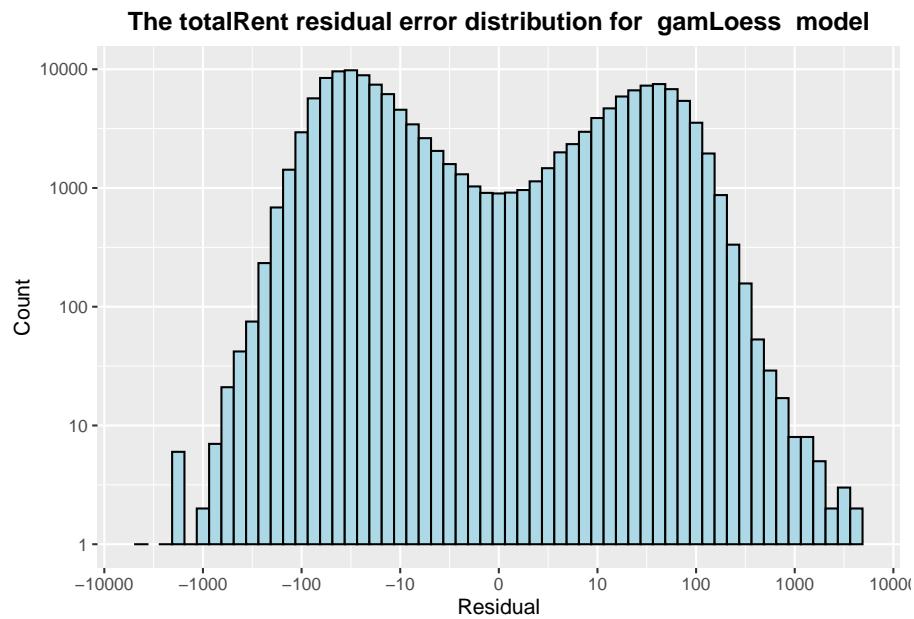
Generalized Additive Model – `gamLoess`

The trained model summary for the `gamLoess` model is not available so we fast forward to the analysis of its residuals.

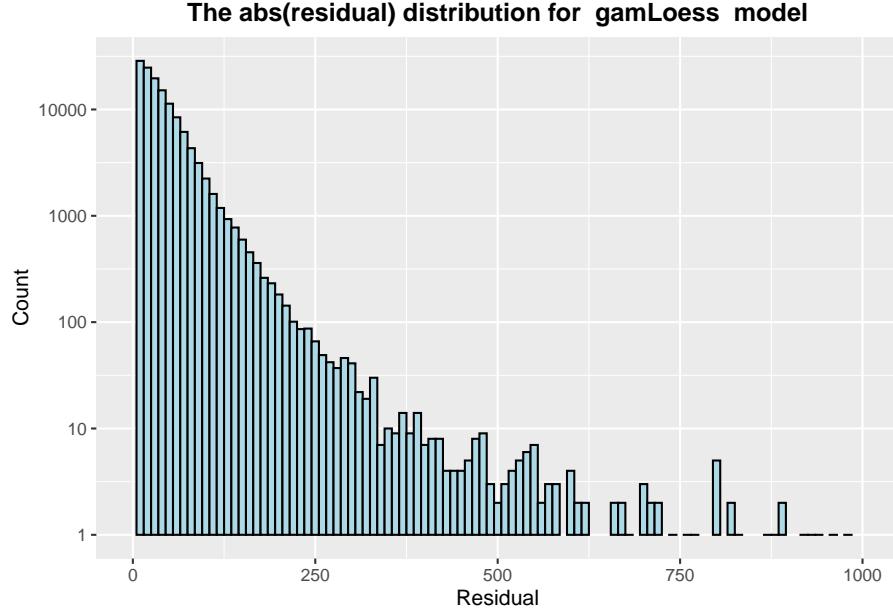
The residuals are spread rather symmetrically around the zero indicating a good model fit:



The histogram of the residual values looks as follows:



The absolute residual values are then distributed as follows:



Note that, the mean absolute residual value is 39.32 and the standard deviation is 232.75.

The RMSE computed on the validation set is 62.38, and it took 4477 seconds to train this model.

Results summary

First we shall summarize the training results for the models:

Table 2: Model Training results

Model	RMSE		AR		Rsquared		MAE	
	Value	SD	Avg	SD	Value	SD	Value	SD
lm	186.96	106.25	40.13	233.26	0.88	0.10	40.08	0.72
glm	211.60	111.48	40.13	233.26	0.86	0.11	40.14	0.79
knn	227.38	102.31	37.72	231.01	0.84	0.11	39.73	0.62
Rborist	258.00	82.30	16.70	102.27	0.82	0.09	40.41	0.57
svmLinear	199.42	101.61	NA	NA	0.87	0.10	40.51	0.78
gamLoess	236.89	103.08	39.32	232.75	0.84	0.10	39.65	0.86

In the table above, we have:

- **RMSE** – the score of the best fit model on the training data;
- **Rsquared** – the R-squared (R^2) statistic;
- **MAE** – the mean absolute error;
- **ARMean** – the mean absolute residual value;

and standard deviations of these metrics. We observe that the **Rsquared** and **MAE** for all the models are very close. The **RMSE** of the **lm** and **svmLinear** seem to be lower (better) than the rest. Also the **AR** values seem to be lower (better) for **knn** and **Rborist**. The latter stands out significantly, which however does not correlate with its **RMSE** core, which is higher than that of all the other models. At the moment we do not have explanations for this “fenomena”.

Let us now consider the summary of the models’ performance on the validation set:

The clear top scoring models, with a marginal difference, are **svmLinear**, **lm**, **glm**, and **gamLoess**. Accounting for the training time, the clear winner is **lm**, with **glm** being very close behind. The other models (**Rborist**,

Table 3: Model Validation results

Model	Summary	
	RMSE	Time (sec)
svmLinear	61.94	7030s (1.95 hours)
lm	62.00	5s
glm	62.00	9s
gamLoess	62.38	4477s (1.24 hours)
Rborist	70.50	2543s (42.38 minutes)
knn	73.80	10556s (2.93 hours)

and `knn`) performed significantly worse, both in RMSE and training times. None of the models was able to achieve the goal `TARGET_RMSE = 50`. Yet, the RMSE of our top model is very close to that.

Let us also note that from analyzing the residuals, it seemed like `Rborist` should perform better in RMSE than other models. The validation results show that it is not the case. Its RMSE score of 70.5 is not impressive. We believe that the reason for that is the over fitting of the model on the training (`modeling`) set. Perhaps, this can be corrected by choosing the right tuning or control parameters for the model but this requires further investigation.

Conclusions

In this project we have taken upon an ambitious goal of building a prediction system for the apartment rental prices in Germany. To reach this goal we have employed supervised Machine Learning techniques studied within the Data Science Professional program at HarvardX. In particular, we have used Bayesian modeling, the ‘Apartment rental offers in Germany’ dataset, and Residual Mean Squared error (RMSE) for evaluating accuracy. The goal was to get a model that has an $\text{RMSE} \leq \text{TARGET_RMSE} = 50$, which would mean that our model could predict the rent price within about 50 Euro, on average.

The considered data set contains 198332 rental offers scraped from the Germany’s biggest real estate online platform ImmobilienScout24. It features important rental property attributes, such as living area size, rent, location, type of energy, and etc. The data scraping was done on three distinct dates: 2019-05-10, 2018-09-22, 2019-10-08 which are also part of the data.

We started our work with data wrangling which revealed that the data set has 48 data columns. This is a large number and therefore we have done an initial selection of 26 columns to be used in this case study. It turned out that the data at hand was also very “dirty”. For instance, about $\frac{1}{2}$ of the columns had 2.5 to 80% of N/A values. Moreover, there were multiple inconsistencies present in the data such as, e.g., lack of coherence between the flat types (e.g. “`rooft_story`”) and the flat floors (e.g. -1). In addition, multiple columns had outlying values, e.g. flats at the 999th floors and alike. All of these were handled by various techniques described in the “*Data wrangling*” section of this report. The cleaned and enriched data was then considered for further reshaping. For instance, the flat’s location, originally split between multiple columns had to be recombined, and etc.

The resulting wrangled data turned out to be 82.06% of the original. We see it as a good result, considering the amount of initial data pollution. Further, the data was split into `modeling` (90% of data) and `validation` (10% of data) sets. The former was also split into `training` and `testing` sub-sets to be used for cross-validation but this turned out to be unnecessary¹¹.

As the next step, we have performed data analyses. First, we checked the data at hand with respect to:

- `timing` effects – whether the scraping dates show any trends
- `location` effects – whether the apartment location has a significant impact on rental prices

¹¹Is explained in one of the subsequent paragraphs.

The former turned out to be not present, whereas the latter one was very vividly present. Then, due to the immense size of the number of predictors (21), we have also performed *correlation analysis* of the predictors' matrix. From which we have observed multiple correlations between different data set columns. The subsequent *Principle Component Analysis* (PCA) has revealed that the first two principle components (PC1 and PC2) explain 99.3% of data variability. This convinced us to use the dimensionality reduction approach employing the PCA rotation matrix.

Since it has been shown that it suffices to use only PC1 and PC2 to explain most of the data variability, it has been decided NOT to build a new statistical model specifically for this case study, but rather to use the existing ones. The visualization of the total rent versus PC1 and PC2 has revealed a clear data clustering suitable for regression models. The modeling approach therefore was to: Take the common *regression models* available via the `caret` package: `lm`, `glm`, `knn`, `Rborist`, `svmLinear`, and `gamLoess`; and use them to predict the total rent prices based on PC1 and PC2.

The model training times are often hard to predict. Therefore, we have decided to limit the training time per model by 1.08×10^4 CPU seconds. This turned out to be sufficient for all of the models at hand. Also, we did not use any specific model control or tuning parameters. The exception was `knn` for which we defined the `k` range. The results revealed that the `lm` model is the fastest (takes 5 seconds to train) and has the top performance ($RMSE = 62$). All the other models, except for comparably performing `glm`; and slightly more accurate, but orders of magnitude slower `svmLinear`, had significantly higher $RMSE$ s and longer training times. See the “*Results summary*” section for more details.

In this study, we have successfully performed all the steps needed to build a rental price prediction system. We did not reach the ambitious `TARGET_RMSE` score but we approached it very closely, even without selecting any special model control or tuning parameters.

Future work

In the future one may consider extending this case study by comparing more different regression models, as well as tuning the used ones for better performance. Also, model ensembles can be taken to improve on the single model performances. One could also try using six first principle components for training the models, as those explain 99.99% of predictors variability.

Appendix A: The complete list of data set columns

Hereby we present the complete list of columns from the original ‘Apartment rental offers in Germany’ dataset:

```
## [1] "regio1"                  "serviceCharge"
## [3] "heatingType"              "telekomTvOffer"
## [5] "telekomHybridUploadSpeed" "newlyConst"
## [7] "balcony"                  "electricityBasePrice"
## [9] "picturecount"             "pricetrend"
## [11] "telekomUploadSpeed"       "totalRent"
## [13] "yearConstructed"          "electricityKwhPrice"
## [15] "scoutId"                  "noParkSpaces"
## [17] "firingTypes"              "hasKitchen"
## [19] "geo_bln"                  "cellar"
## [21] "yearConstructedRange"     "baseRent"
## [23] "houseNumber"              "livingSpace"
## [25] "geo_krs"                  "condition"
## [27] "interiorQual"             "petsAllowed"
## [29] "streetPlain"              "lift"
```

```

## [31] "baseRentRange"           "typeOfFlat"
## [33] "geo_plz"                "noRooms"
## [35] "thermalChar"             "floor"
## [37] "numberOfWorks"            "noRoomsRange"
## [39] "garden"                  "livingSpaceRange"
## [41] "regio2"                   "regio3"
## [43] "description"              "facilities"
## [45] "heatingCosts"             "energyEfficiencyClass"
## [47] "lastRefurbish"            "date"

```

Appendix B: Data set column descriptions

Here is the list of the initially considered data set columns with the descriptions thereof:

1. **hasKitchen** – has a kitchen
2. **balcony** – does the object have a balcony
3. **cellar** – has a cellar
4. **lift** – is elevator available
5. **floor** – which floor is the flat on
6. **garden** – has a garden
7. **noParkSpaces** – number of parking spaces
8. **livingSpace** – living space in sqm
9. **condition** – condition of the flat
10. **interiorQual** – interior quality
11. **regio1** – Bundesland
12. **regio2** - District or Kreis, same as geo krs
13. **regio3** – City/town
14. **noRooms** – number of rooms
15. **numberOfWorks** – number of floors in the building
16. **typeOfFlat** – type of flat
17. **yearConstructed** – construction year
18. **newlyConst** – is the building newly constructed
19. **heatingType** – Type of heating
20. **energyEfficiencyClass** – energy efficiency class
21. **heatingCosts** – monthly heating costs in €
22. **serviceCharge** – auxiliary costs such as electricity or Internet in €
23. **electricityBasePrice** – monthly base price for electricity in €
24. **baseRent** – base rent without electricity and heating
25. **totalRent** – total rent (usually a sum of base rent, service charge and heating cost)
26. **date** – time of scraping