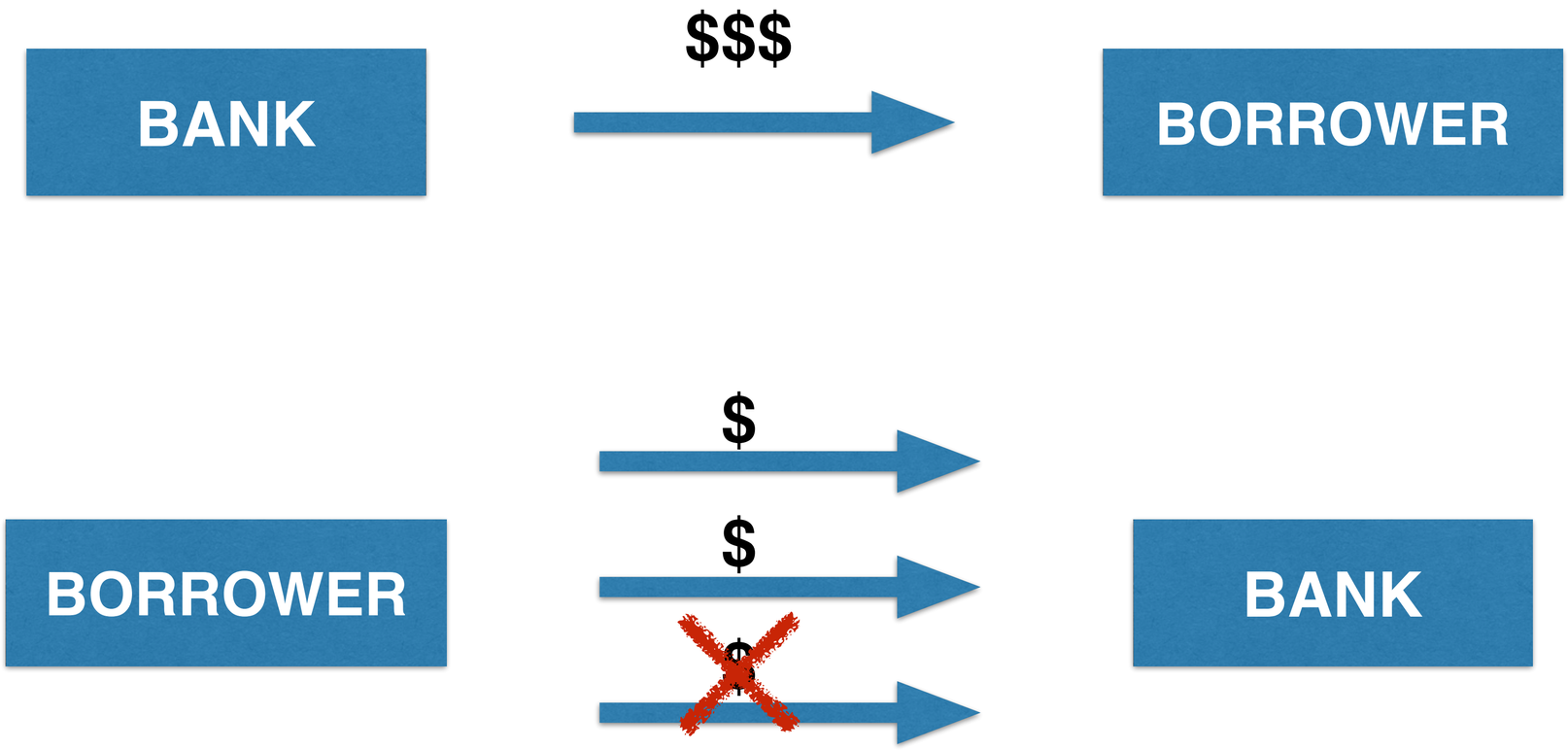
CREDIT RISK MODELING IN R

Introduction and data structure

What is loan default?



Components of expected loss (EL)

- Probability of default (PD)
- Exposure at default (EAD)
- Loss given default (LGD)

$$EL = PD \times EAD \times LGD$$

Information used by banks

- Application information:
  - income
  - marital status
  - ...
- Behavioral information
  - current account balance
  - payment arrears in account history
  - ...

The data

```
> head(loan_data, 10)
   loan_status loan_amnt int_rate grade emp_length home_ownership annual_inc age
1            0      5000    10.65     B          10           RENT      24000  33
2            0      2400       NA     C          25           RENT      12252  31
3            0     10000    13.49     C          13           RENT      49200  24
4            0      5000       NA     A           3           RENT      36000  39
5            0      3000       NA     E           9           RENT      48000  24
6            0     12000    12.69     B          11            OWN      75000  28
7            1      9000    13.49     C           0           RENT      30000  22
8            0      3000     9.91     B           3           RENT      15000  22
9            1     10000    10.65     B           3           RENT     100000  28
10           0      1000    16.29     D           0           RENT      28000  22
```

CrossTable

```
> library(gmodels)
> CrossTable(loan_data$home_ownership)

   Cell Contents
|-------------------------|
|                       N |
|         N / Table Total |
|-------------------------|


Total Observations in Table:  29092


           |  MORTGAGE |     OTHER |       OWN |      RENT |
           |-----------|-----------|-----------|-----------|
           |     12002 |        97 |      2301 |     14692 |
           |     0.413 |     0.003 |     0.079 |     0.505 |
           |-----------|-----------|-----------|-----------|
```

CrossTable

```
> CrossTable(loan_data$home_ownership, loan_data$loan_status, prop.r = TRUE,
prop.c = FALSE, prop.t = FALSE, prop.chisq = FALSE)

                           | loan_data$loan_status
loan_data$home_ownership   |         0 |         1 | Row Total |
---------------------------|-----------|-----------|-----------|
                  MORTGAGE |     10821 |      1181 |     12002 |
                           |     0.902 |     0.098 |     0.413 |
---------------------------|-----------|-----------|-----------|
                     OTHER |        80 |        17 |        97 |
                           |     0.825 |     0.175 |     0.003 |
---------------------------|-----------|-----------|-----------|
                       OWN |      2049 |       252 |      2301 |
                           |     0.890 |     0.110 |     0.079 |
---------------------------|-----------|-----------|-----------|
                      RENT |     12915 |      1777 |     14692 |
                           |     0.879 |     0.121 |     0.505 |
---------------------------|-----------|-----------|-----------|
              Column Total |     25865 |      3227 |     29092 |
---------------------------|-----------|-----------|-----------|
```

CREDIT RISK MODELING IN R

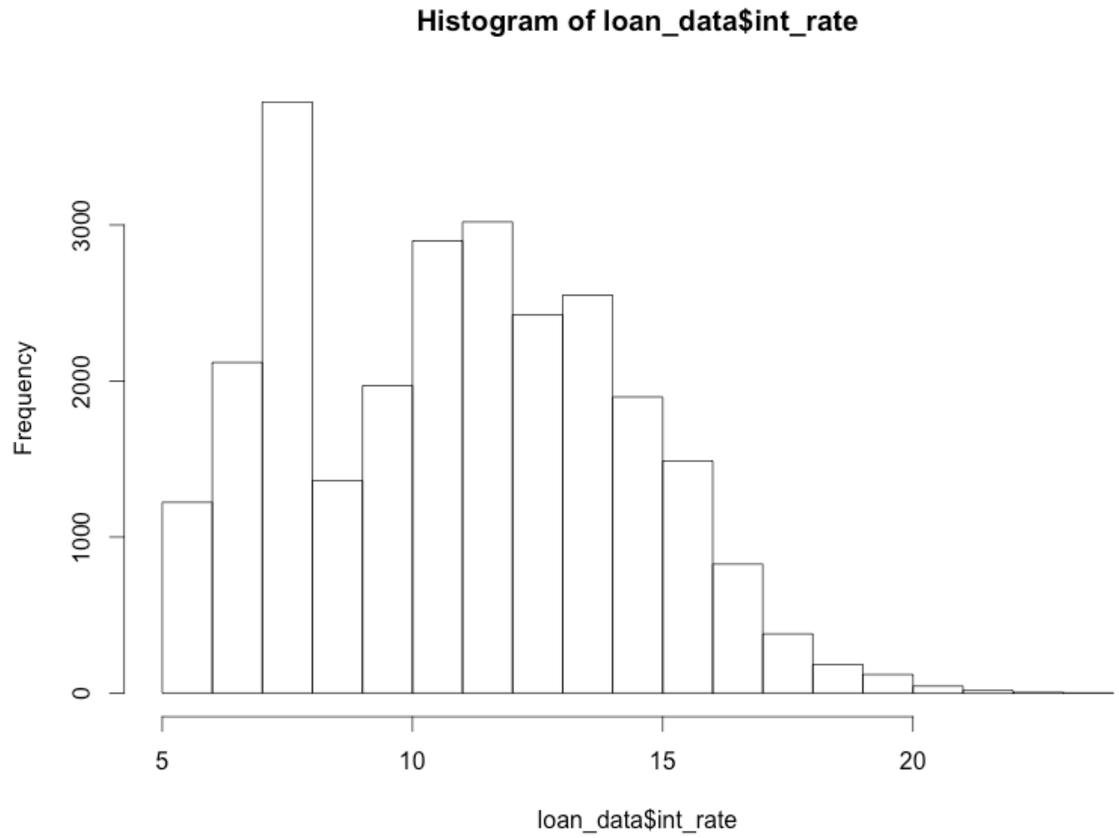
Let’s practice!

CREDIT RISK MODELING IN R

Histograms and outliers

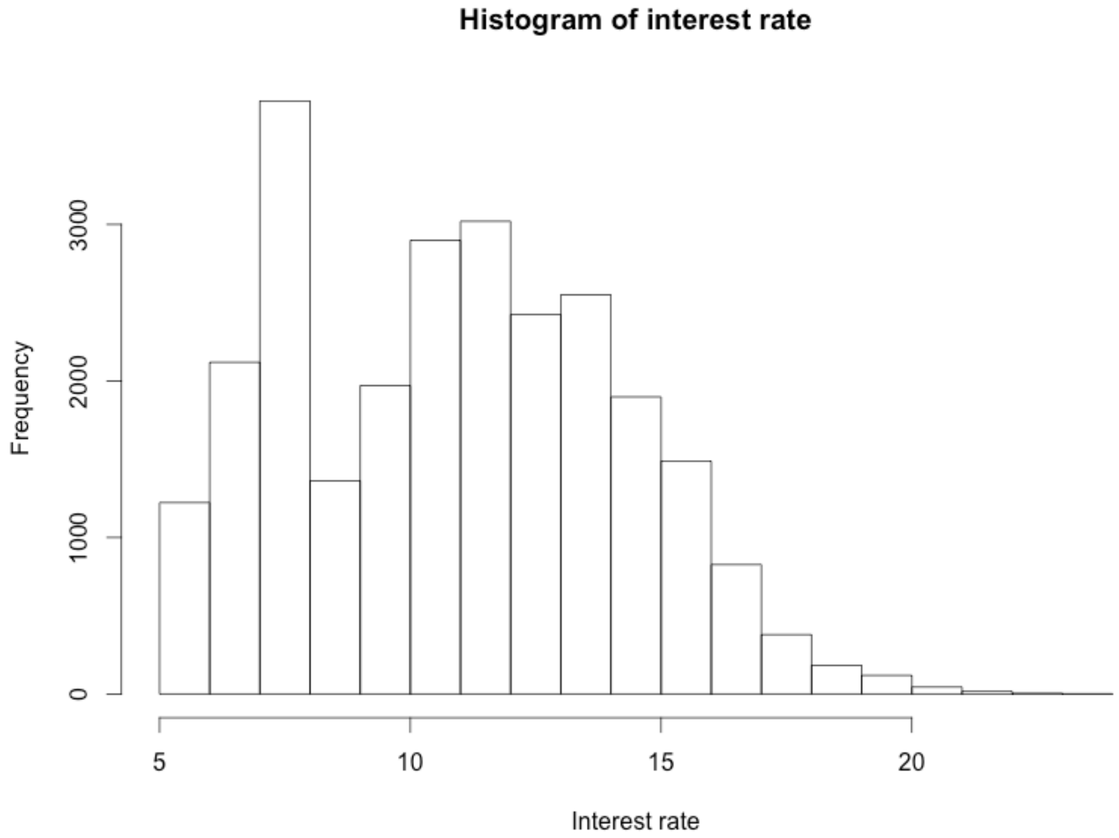
Using function hist()

```
> hist(loan_data$int_rate)
```



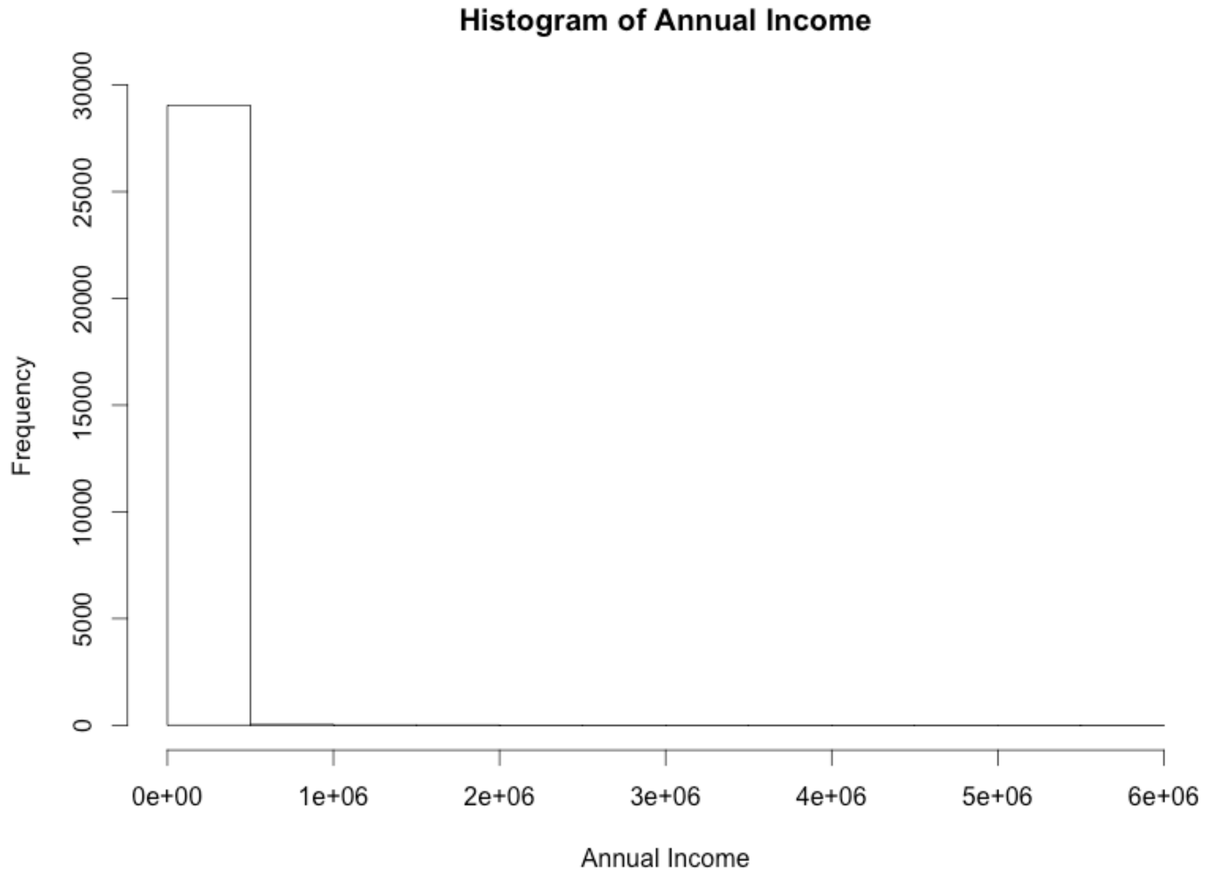
Using function hist()

```
> hist(loan_data$int_rate, main = "Histogram of interest rate", xlab = "Interest rate")
```



Using function hist() on annual_inc

```
hist(loan_data$annual_inc, xlab= "Annual Income”, main= "Histogram of Annual Income")
```

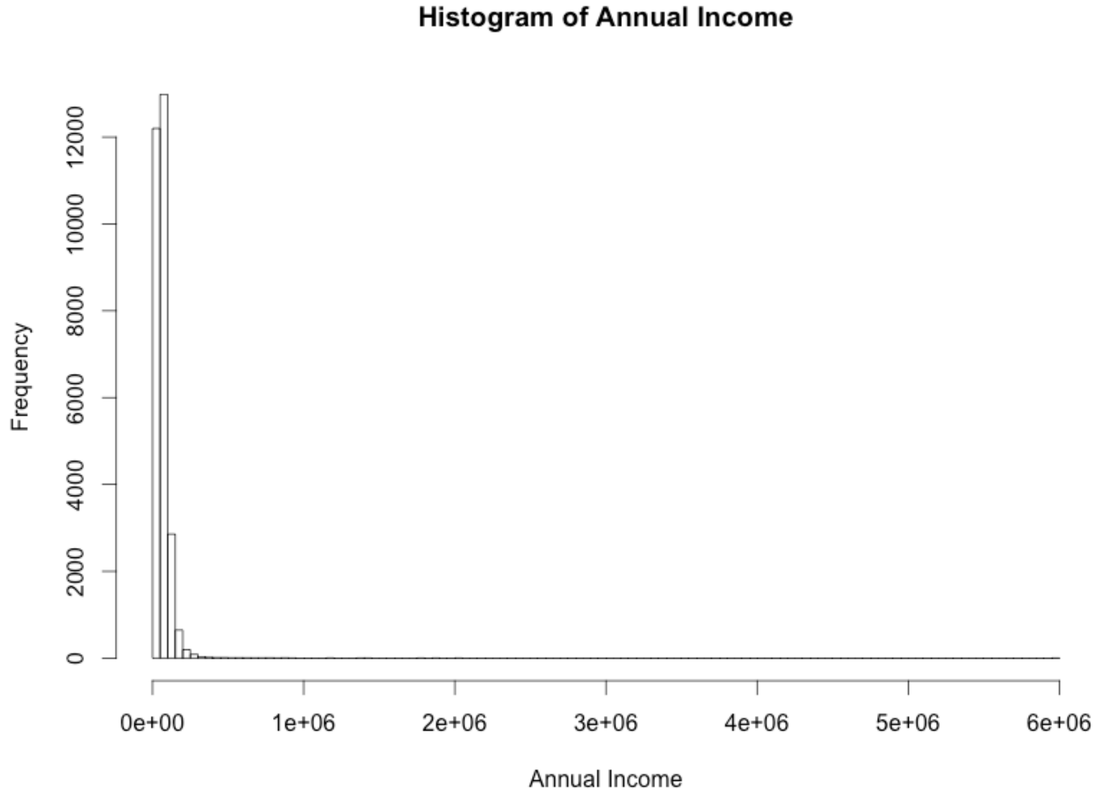


Using function hist() on annual_inc

```
> hist_income <- hist(loan_data$annual_inc, xlab = "Annual Income”, main =
"Histogram of Annual Income”)

> hist_income$breaks
 [1]       0  500000 1000000 1500000 2000000 2500000 3000000 3500000 4000000
4500000 5000000 5500000 6000000
```

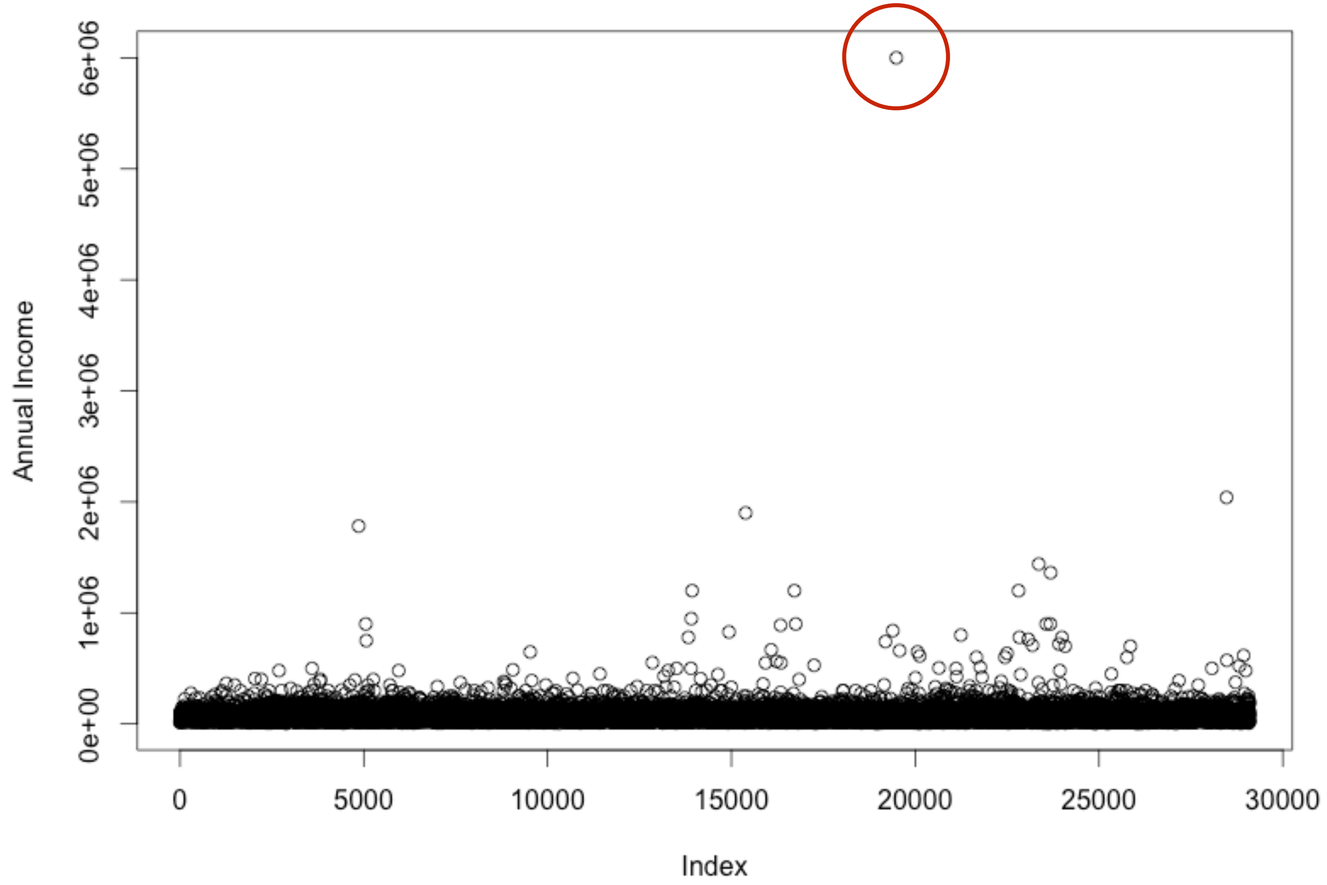
The breaks-argument

```
> n_breaks <- sqrt(nrow(loan_data)) # = 170.5638

> hist_income_n <- hist(loan_data$annual_inc, breaks= n_breaks, xlab = "Annual
Income”, main = "Histogram of Annual Income")
```



annual_inc

```
plot(loan_data$annual_inc, ylab = "Annual Income")
```



Outliers

- When is a value an outlier?
  - expert judgement
  - rule of thumb: Q1 - 1.5 * IQR
    Q3 + 1.5 * IQR
  - mostly: combination of both

Expert judgement - rule of thumb

“Annual salaries > $ 3 million are outliers”

```
> index_outlier_expert <- which(loan_data$annual_inc > 3000000)

> loan_data_expert <- loan_data[-index_outlier_expert, ]
```

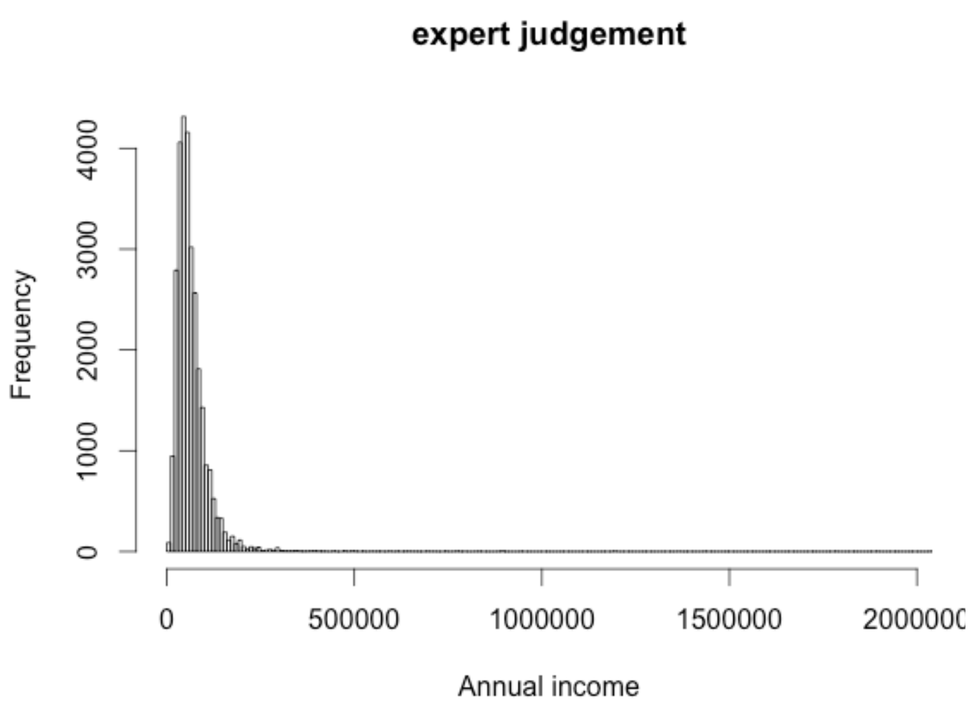
Use of a rule of thumb: outlier if bigger than Q3 + 1.5 * IQR

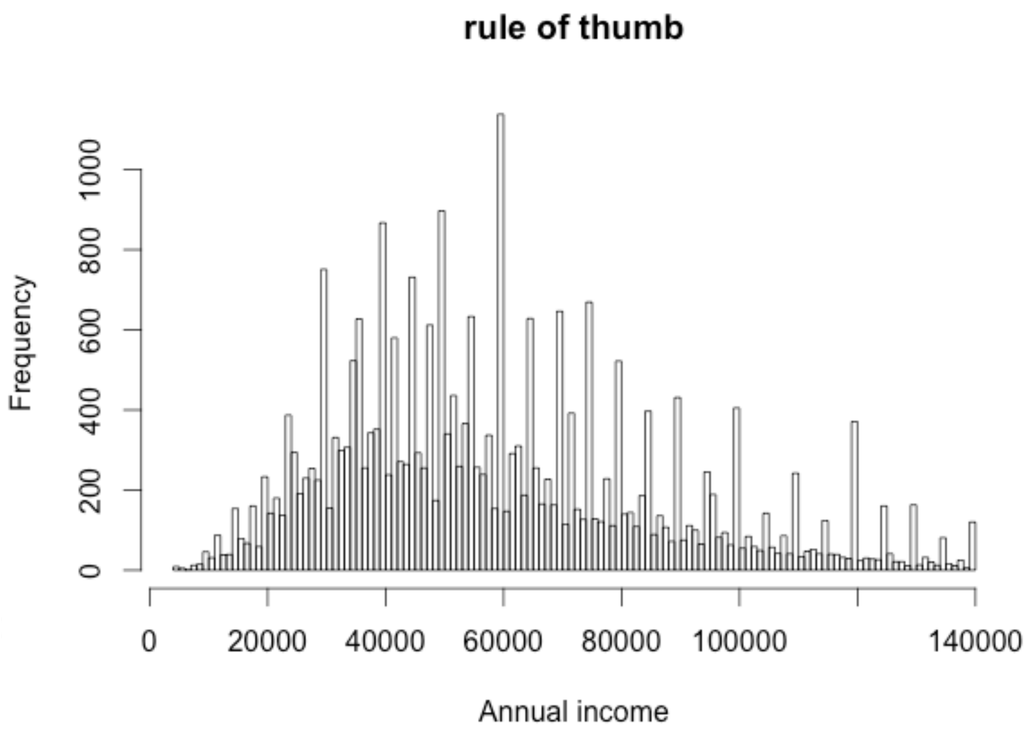
```
outlier_cutoff <- quantile(loan_data$annual_inc, 0.75) + 1.5 * IQR(loan_data$annual_inc)

index_outlier_ROT <- which(loan_data$annual_inc > outlier_cutoff)

loan_data_ROT <- loan_data[-index_outlier_ROT, ]
```

histograms

```
hist(loan_data_expert$annual_inc,
sqrt(nrow(loan_data_expert)), xlab =
"Annual income expert judgement”)
```

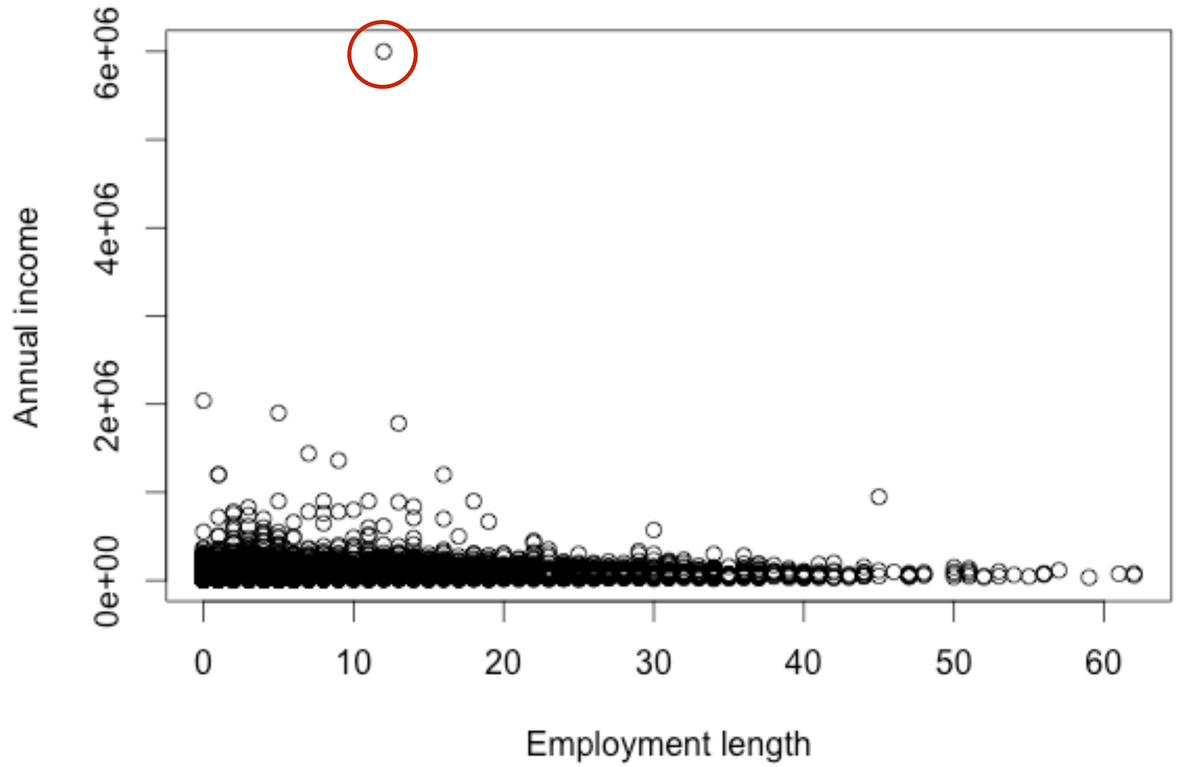
```
hist(loan_data_ROT$annual_inc,
sqrt(nrow(loan_data_ROT)), xlab =
"Annual income rule of thumb")
```





bivariate plot

```
plot(loan_data$emp_length, loan_data$annual_inc, xlab= "Employment length”,
ylab= "Annual income")
```



CREDIT RISK MODELING IN R

Let’s practice!

CREDIT RISK MODELING IN R

Missing data and coarse classification

Outlier deleted

loan_status	loan_amnt	int_rate	grade	emp_length	home_ownership	annual_inc	age
0	5000	12.73	C	12	MORTGAGE	6000000	144

Missing inputs

	loan_status	loan_amnt	int_rate	grade	emp_length	home_ownership	annual_inc	age
…	…	…	…	…	…	…	…	…
125	0	6000	14.27	C	14	MORTGAGE	94800	23
126	1	2500	7.51	A	NA	OWN	12000	21
127	0	13500	9.91	B	2	MORTGAGE	36000	30
128	0	25000	12.42	B	2	RENT	225000	30
129	0	10000	NA	C	2	RENT	45900	65
130	0	2500	13.49	C	4	RENT	27200	26
…	…	…	…	…	…	…	…	…
2108	0	8000	7.90	A	8	RENT	64000	24
2109	0	12000	8.90	A	0	RENT	38400	26
2110	0	4000	NA	A	7	RENT	48000	30
2111	0	7000	9.91	B	20	MORTGAGE	130000	30
2112	0	7600	6.03	A	41	MORTGAGE	70920	28
2113	0	10000	11.71	B	5	RENT	48132	22
2114	0	8000	6.62	A	17	OWN	42000	24
2115	0	4475	NA	B	NA	OWN	15000	23
2116	0	5750	8.90	A	3	RENT	17000	21
2117	0	4900	6.03	A	12	MORTGAGE	77000	27
…	…	…	…	…	…	…	…	…

Missing inputs

```
> summary(loan_data$emp_length)

   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.    NA's
  0.000   2.000   4.000   6.145   8.000  62.000     809
```

Missing inputs: strategies

- Delete row/column
- Replace
- Keep

Delete rows

```
index_NA <- which(is.na(loan_data$emp_length)
loan_data_no_NA <- loan_data[-c(index_NA), ]
```

```
     loan_status loan_amnt  int_rate  grade  emp_length home_ownership annual_inc age
  …          …         …         …      …          …              …          …    …
125          0      6000      14.27      C         14       MORTGAGE      94800   23
126          1      2500       7.51      A         NA            OWN      12000   21
127          0     13500       9.91      B          2       MORTGAGE      36000   30
128          0     25000      12.42      B          2           RENT     225000   30
129          0     10000         NA      C          2           RENT      45900   65
130          0      2500      13.49      C          4           RENT      27200   26
  …          …         …         …      …          …              …          …    …
2112         0      7600       6.03      A         41       MORTGAGE      70920   28
2113         0     10000      11.71      B          5           RENT      48132   22
2114         0      8000       6.62      A         17            OWN      42000   24
2115         0      4475         NA      B         NA            OWN      15000   23
2116         0      5750       8.90      A          3           RENT      17000   21
  …          …         …         …      …          …              …          …    …
```

Delete column

```
loan_data_delete_employ <- loan_data
loan_data_delete_employ$emp_length <- NULL
```

```
     loan_status loan_amnt  int_rate  grade  emp_length home_ownership annual_inc age
  …          …         …         …      …          …              …          …    …
125          0      6000      14.27      C         14       MORTGAGE      94800   23
126          1      2500       7.51      A         NA            OWN      12000   21
127          0     13500       9.91      B          2       MORTGAGE      36000   30
128          0     25000      12.42      B          2           RENT     225000   30
129          0     10000         NA      C          2           RENT      45900   65
130          0      2500      13.49      C          4           RENT      27200   26
  …          …         …         …      …          …              …          …    …
2112         0      7600       6.03      A         11       MORTGAGE      70920   28
2113         0     10000      11.71      B          5           RENT      48132   22
2114         0      8000       6.62      A         17            OWN      42000   24
2115         0      4475         NA      B         NA            OWN      15000   23
2116         0      5750       8.90      A          3           RENT      17000   21
  …          …         …         …      …          …              …          …    …
```

Replace: median imputation

```
index_NA <- which(is.na(loan_data$emp_length)
loan_data_replace <- loan_data
loan_data_replace$emp_length[index_NA] <- median(loan_data$emp_length, na.rm = TRUE)
```

```
     loan_status loan_amnt  int_rate  grade  emp_length home_ownership annual_inc age
  …          …         …         …      …          …              …          …    …
125          0      6000      14.27      C         14       MORTGAGE      94800   23
126          1      2500       7.51      A         NA            OWN      12000   21
127          0     13500       9.91      B          2       MORTGAGE      36000   30
128          0     25000      12.42      B          2           RENT     225000   30
129          0     10000         NA      C          2           RENT      45900   65
130          0      2500      13.49      C          4           RENT      27200   26
  …          …         …         …      …          …              …          …    …
2112         0      7600       6.03      A         41       MORTGAGE      70920   28
2113         0     10000      11.71      B          5           RENT      48132   22
2114         0      8000       6.62      A         17            OWN      42000   24
2115         0      4475         NA      B         NA            OWN      15000   23
2116         0      5750       8.90      A          3           RENT      17000   21
  …          …         …         …      …          …              …          …    …
```

Replace: median imputation

```
index_NA <- which(is.na(loan_data$emp_length)
loan_data_replace <- loan_data
loan_data_replace$emp_length[index_NA] <- median(loan_data$emp_length, na.rm = TRUE)
```

```
     loan_status loan_amnt  int_rate  grade  emp_length home_ownership annual_inc age
  …          …         …         …      …          …              …          …    …
125          0      6000      14.27      C         14       MORTGAGE      94800   23
126          1      2500       7.51      A          4            OWN      12000   21
127          0     13500       9.91      B          2       MORTGAGE      36000   30
128          0     25000      12.42      B          2           RENT     225000   30
129          0     10000         NA      C          2           RENT      45900   65
130          0      2500      13.49      C          4           RENT      27200   26
  …          …         …         …      …          …              …          …    …
2112         0      7600       6.03      A         41       MORTGAGE      70920   28
2113         0     10000      11.71      B          5           RENT      48132   22
2114         0      8000       6.62      A         17            OWN      42000   24
2115         0      4475         NA      B          4            OWN      15000   23
2116         0      5750       8.90      A          3           RENT      17000   21
  …          …         …         …      …          …              …          …    …
```

Keep

- Keep NA
- Problem: will cause row deletions for many models
- Solution: coarse classification, put variable in “bins”
  - new variable emp_cat
  - range: 0-62 years —> make bins of +/- 15 years
  - categories: “0-15”, “15-30”, “30-45”, “45+”, “missing”

Keep: coarse classification

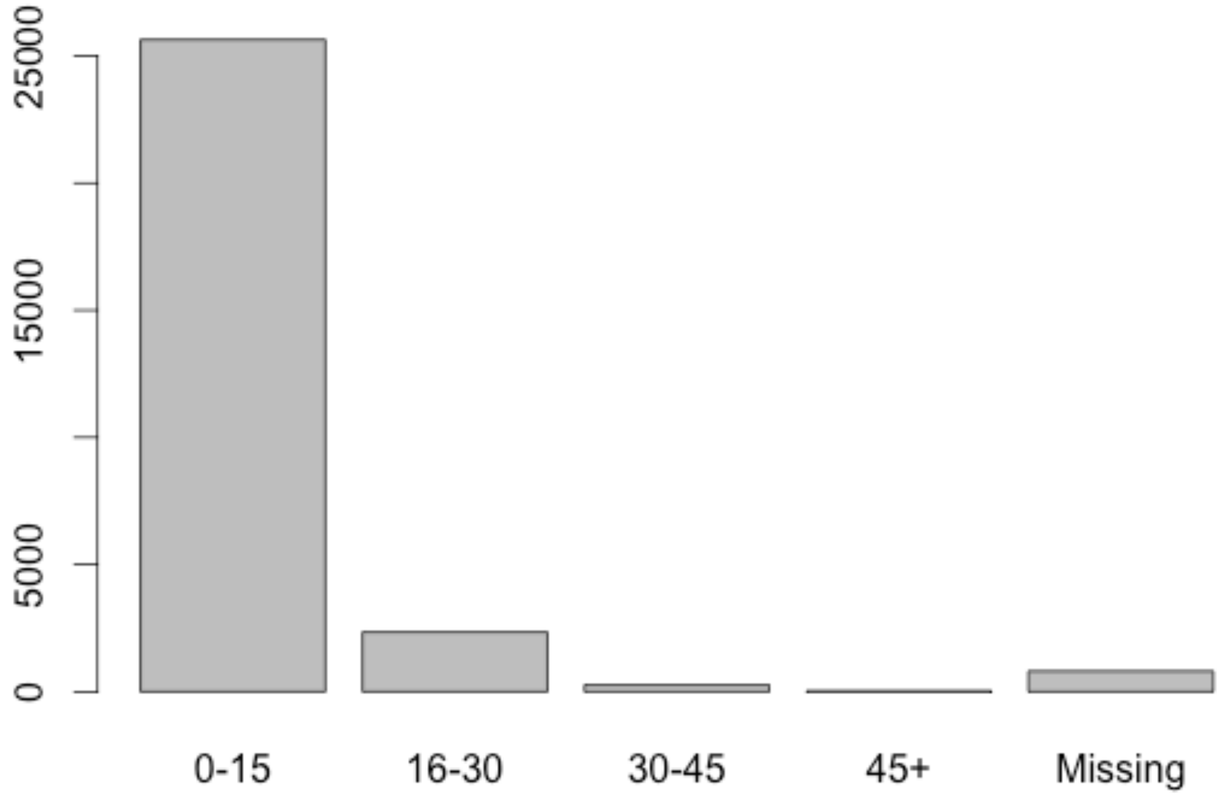
	loan_status	loan_amnt	int_rate	grade	emp_length	home_ownership	annual_inc	age
…	…	…	…	…	…	…	…	…
125	0	6000	14.27	C	14	MORTGAGE	94800	23
126	1	2500	7.51	A	NA	OWN	12000	21
127	0	13500	9.91	B	2	MORTGAGE	36000	30
128	0	25000	12.42	B	2	RENT	225000	30
129	0	10000	NA	C	2	RENT	45900	65
130	0	2500	13.49	C	4	RENT	27200	26
…	…	…	…	…	…	…	…	…
2112	0	7600	6.03	A	41	MORTGAGE	70920	28
2113	0	10000	11.71	B	5	RENT	48132	22
2114	0	8000	6.62	A	17	OWN	42000	24
2115	0	4475	NA	B	NA	OWN	15000	23
2116	0	5750	8.90	A	3	RENT	17000	21
…	…	…	…	…	…	…	…	…

Keep: coarse classification

	loan_status	loan_amnt	int_rate	grade	emp_cat	home_ownership	annual_inc	age
…	…	…	…	…	…	…	…	…
125	0	6000	14.27	C	0-15	MORTGAGE	94800	23
126	1	2500	7.51	A	Missing	OWN	12000	21
127	0	13500	9.91	B	0-15	MORTGAGE	36000	30
128	0	25000	12.42	B	0-15	RENT	225000	30
129	0	10000	NA	C	0-15	RENT	45900	65
130	0	2500	13.49	C	0-15	RENT	27200	26
…	…	…	…	…	…	…	…	…
2112	0	7600	6.03	A	30-45	MORTGAGE	70920	28
2113	0	10000	11.71	B	0-15	RENT	48132	22
2114	0	8000	6.62	A	15-30	OWN	42000	24
2115	0	4475	NA	B	Missing	OWN	15000	23
2116	0	5750	8.90	A	0-15	RENT	17000	21
…	…	…	…	…	…	…	…	…

Bin frequencies

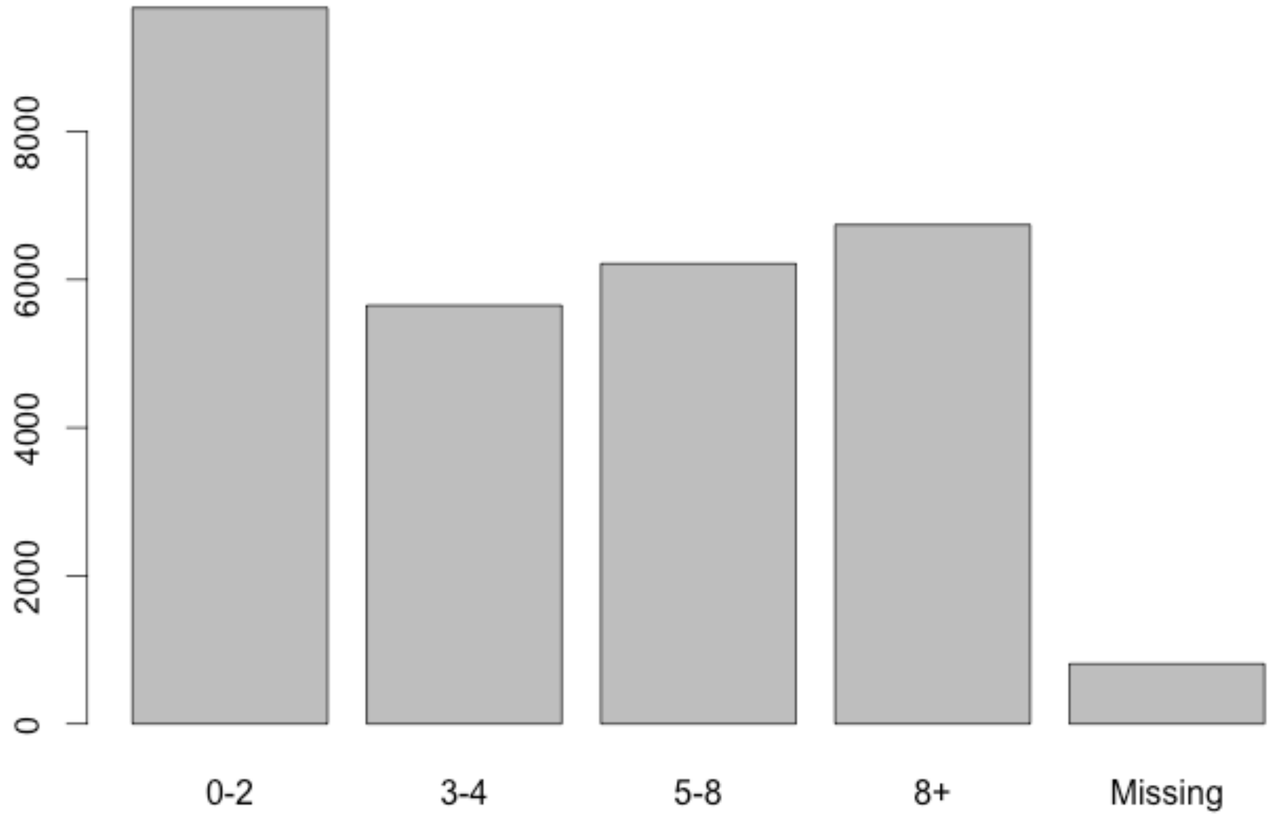
```
plot(loan_data$emp_cat)
```




```
    emp_cat
       …
     0-15
Missing
     0-15
     0-15
     0-15
     0-15
       …
    30-45
     0-15
    15-30
Missing
     0-15
       …
```

Bin frequencies

```
plot(loan_data$emp_cat)
```




```
emp_cat
      …
     8+
Missing
    0-2
    0-2
    0-2
    3-4
      …
     8+
    5-8
     8+
Missing
    3-4
      …
```

Final remarks

	CONTINUOUS	CATEGORICAL
DELETE	Delete rows (observations with NAs) Delete column (entire variable)	Delete rows (observations with NAs) Delete column (entire variable)
REPLACE	replace using median	replace using most frequent category
KEEP	keep as NA (not always possible) keep using coarse classification	NA category

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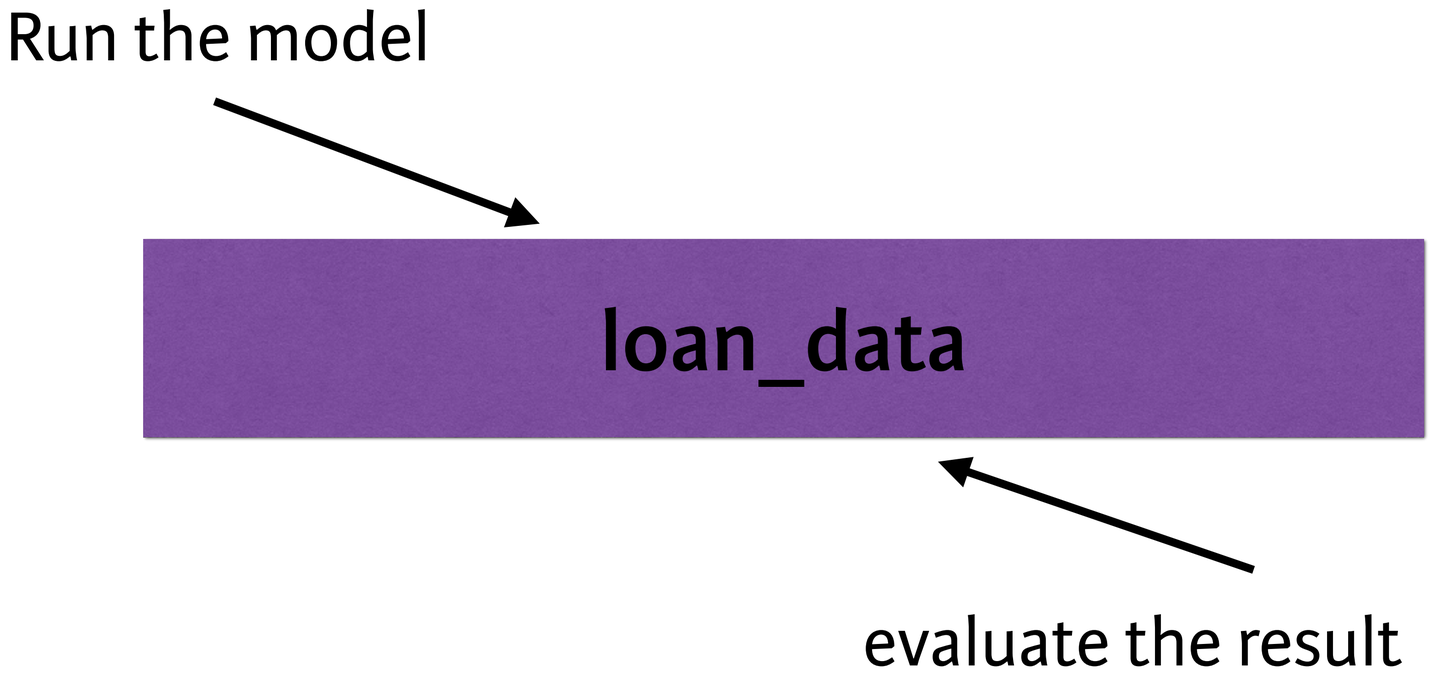
Let’s practice!

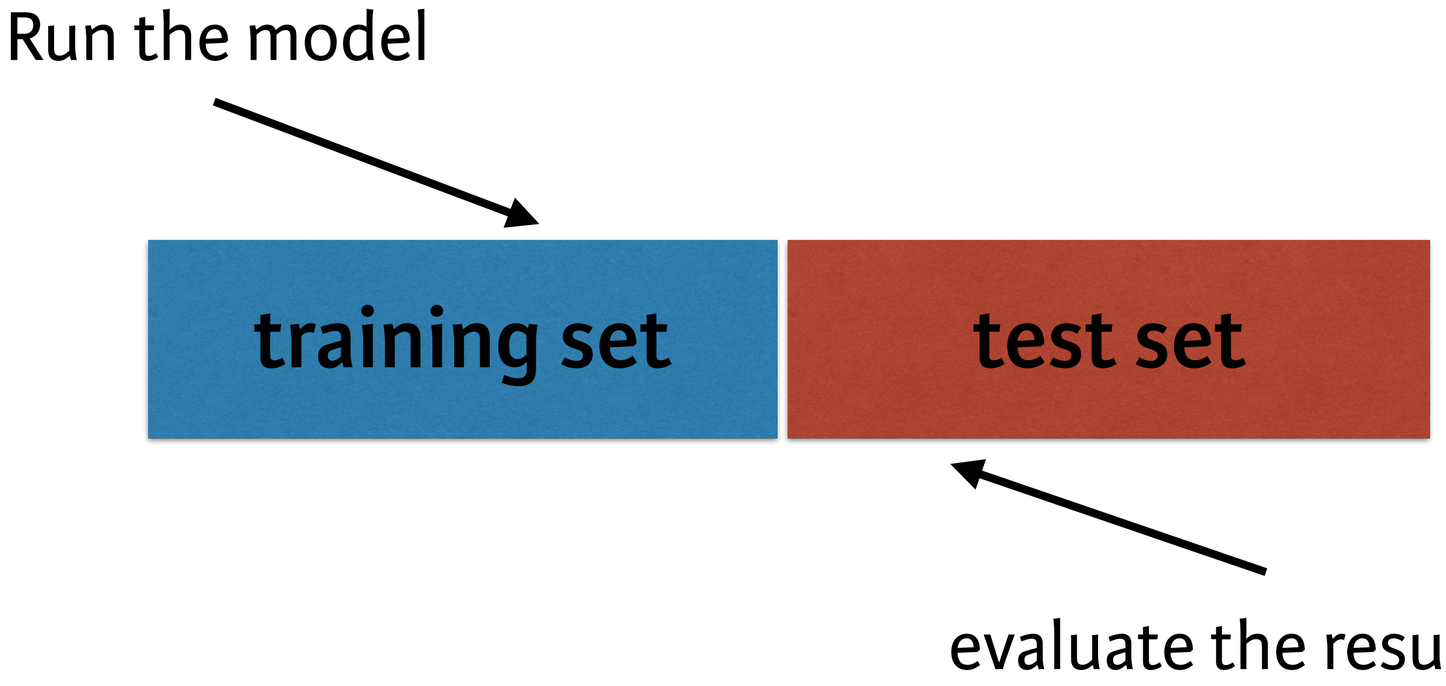
CREDIT RISK MODELING IN R

Data splitting and confusion matrices

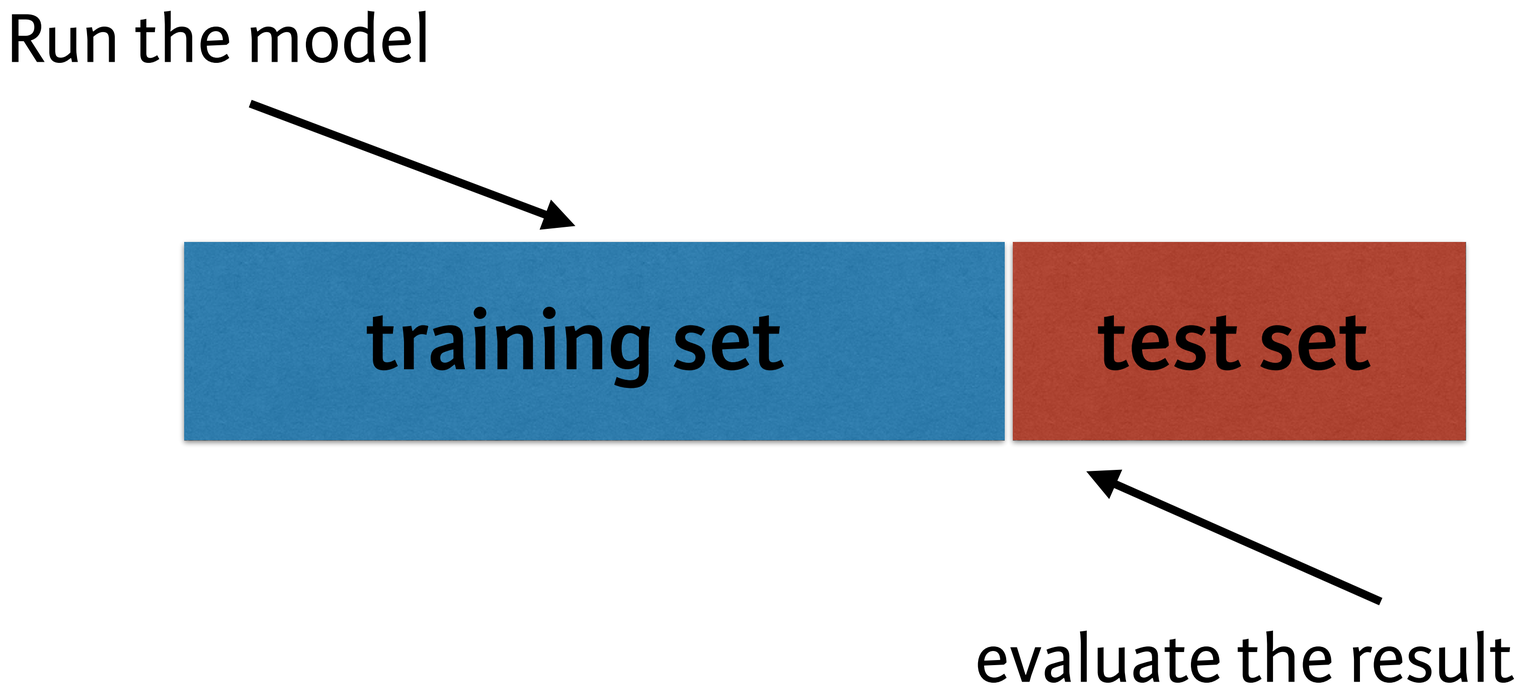
Start analysis



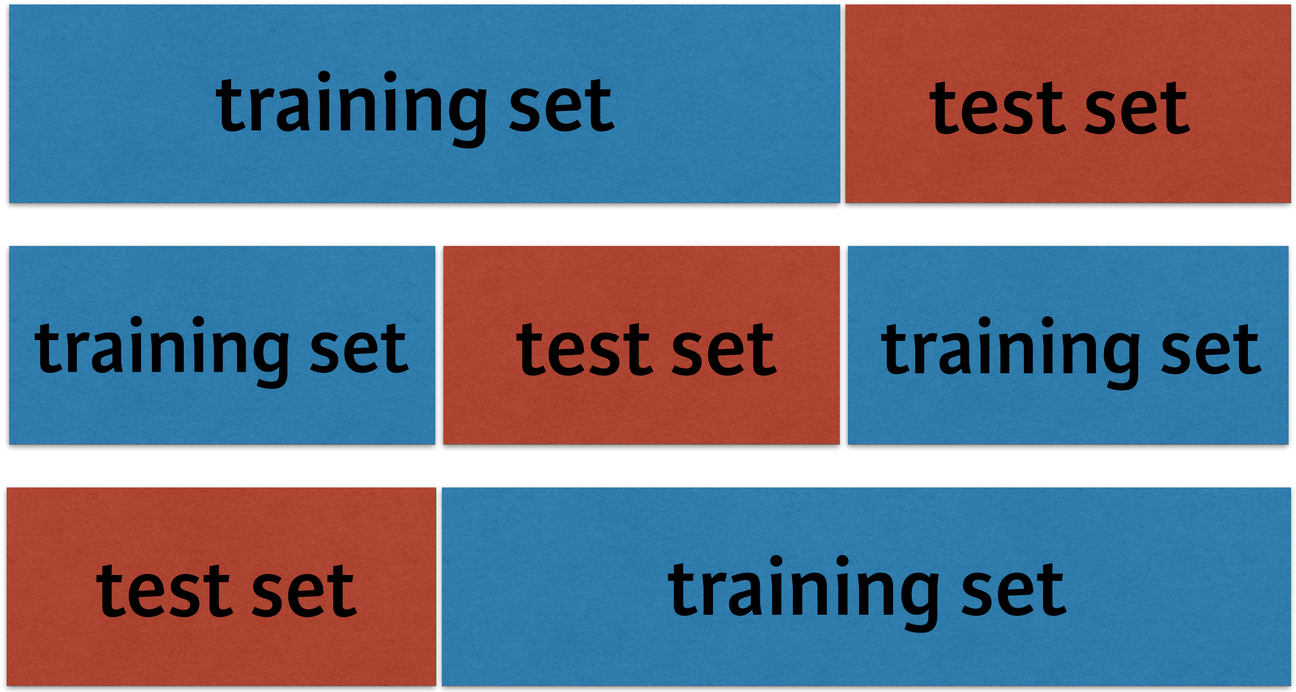
training and test set



training and test set



cross-validation



evaluate a model

	test_set$loan_status	model_prediction
	…	…
[8066,]	1	1
[8067,]	0	0
[8068,]	0	0
[8069,]	0	0
[8070,]	0	0
[8071,]	0	1
[8072,]	1	0
[8073,]	1	1
[8074,]	0	0
[8075,]	0	0
[8076,]	0	0
[8077,]	1	1
[8078,]	0	0
[8079,]	0	1
	…	…

model prediction

actual loan status

	no default (0)	default (1)
no default (0)	8	2
default (1)	1	3

evaluate a model

	test_set$loan_status	model_prediction
	…	…
[8066,]	1	1
[8067,]	0	0
[8068,]	0	0
[8069,]	0	0
[8070,]	0	0
[8071,]	0	1
[8072,]	1	0
[8073,]	1	1
[8074,]	0	0
[8075,]	0	0
[8076,]	0	0
[8077,]	1	1
[8078,]	0	0
[8079,]	0	1
	…	…

model prediction

actual loan status

	no default (0)	default (1)
no default (0)	**TN**	**FP**
default (1)	**FN**	**TP**

some measures...

- Accuracy = (8 + 3) / 14 = 78.57%
- Sensitivity = 3 / (1 + 3) = 75 %
- Specificity = 8/ (8 + 2)= 80%

model prediction

actual loan status

	no default (0)	default (1)
no default (0)	8	2
default (1)	1	3

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Let’s practice!