Bank Dataset

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Clear workspace

```
clear all; clc; close all;
```

Initialize variables

Load tables

```
training_set = readtable('bank-sample.csv')
```

```
training_set = 2000×17 table
```

...

	age	job	marital	education	default	balance	housing
1	31	'management'	'single'	'tertiary'	'no'	0	'yes'
2	45	'entrepreneur'	'married'	'tertiary'	'no'	1752	'yes'
3	46	'services'	'divorced'	'secondary'	'no'	4329	'no'
4	35	'management'	'married'	'tertiary'	'no'	1108	'yes'
5	39	'management'	'married'	'secondary'	'no'	1410	'yes'
6	31	'management'	'single'	'tertiary'	'no'	499	'yes'
7	34	'entrepreneur'	'married'	'tertiary'	'no'	0	'yes'
8	39	'admin.'	'married'	'secondary'	'no'	26233	'no'
9	38	'blue-collar'	'married'	'secondary'	'no'	8444	'yes'
10	50	'management'	'married'	'tertiary'	'yes'	72	'no'
11	58	'blue-collar'	'married'	'secondary'	'no'	1075	'yes'
12	36	'management'	'divorced'	'secondary'	'no'	47	'no'
13	35	'blue-collar'	'married'	'secondary'	'no'	635	'yes'
14	72	'retired'	'married'	'secondary'	'no'	17739	'no'

⋮

```
test_set = readtable('bank-sample-test.csv');
```

Transform dates

```
training_set.date = datenum(strcat(num2str(training_set.day),training_set.month),'ddmmm');
test_set.date = datenum(strcat(num2str(test_set.day),test_set.month),'ddmmm');
```

Transform logarithmic variables

```
training_set.balance  = log(max(training_set.balance,1));
training_set.duration = log(training_set.duration + 1);
```

```
test_set.balance  = log(max(test_set.balance,1));
test_set.duration = log(test_set.duration + 1);
```

Transform categorical variables

```
training_set.job       = categorical(training_set.job);
training_set.marital   = categorical(training_set.marital);
training_set.education = categorical(training_set.education);
training_set.default   = categorical(training_set.default);
training_set.housing   = categorical(training_set.housing);
training_set.loan      = categorical(training_set.loan);
training_set.contact   = categorical(training_set.contact);
training_set.month     = categorical(training_set.month);
training_set.month     = reordercats(training_set.month, ["jan","feb","mar","apr","may","jun","
training_set.poutcome  = categorical(training_set.poutcome);

training_set.subscribed = categorical(training_set.subscribed);
```

```
test_set.job       = categorical(test_set.job);
test_set.marital   = categorical(test_set.marital);
test_set.education = categorical(test_set.education);
test_set.default   = categorical(test_set.default);
test_set.housing   = categorical(test_set.housing);
test_set.loan      = categorical(test_set.loan);
test_set.contact   = categorical(test_set.contact);
test_set.month     = categorical(test_set.month);
test_set.month     = reordercats(test_set.month, ["jan","feb","mar","apr","may","jun","jul","au
test_set.poutcome  = categorical(test_set.poutcome);

test_set.subscribed = categorical(test_set.subscribed);
```

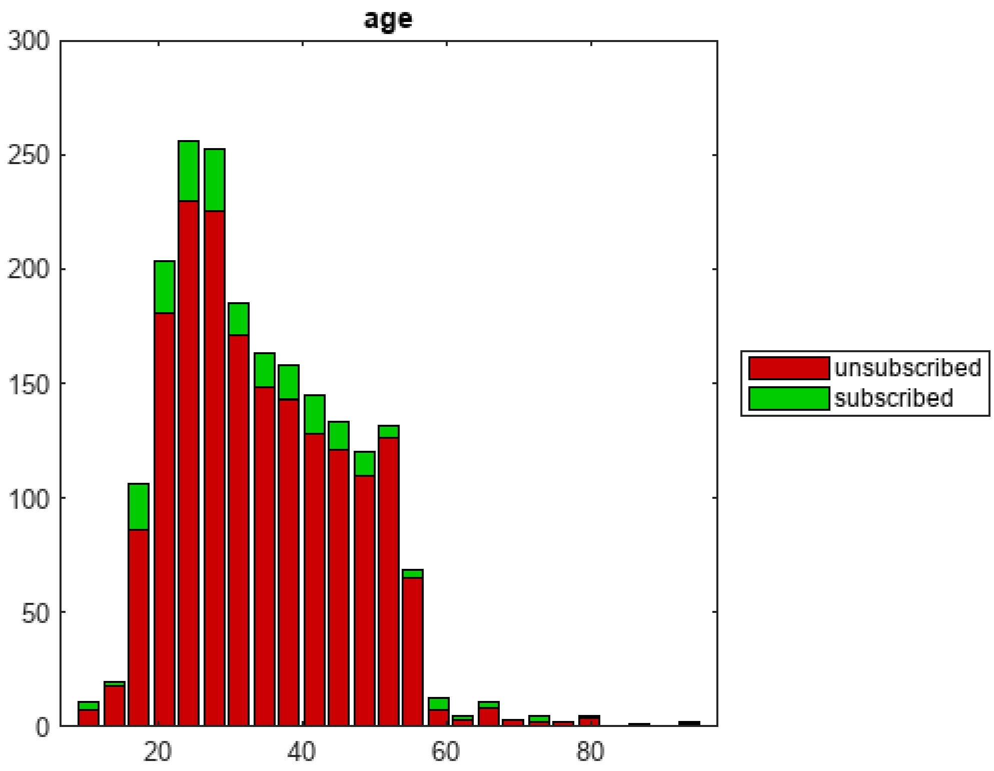
Explore data

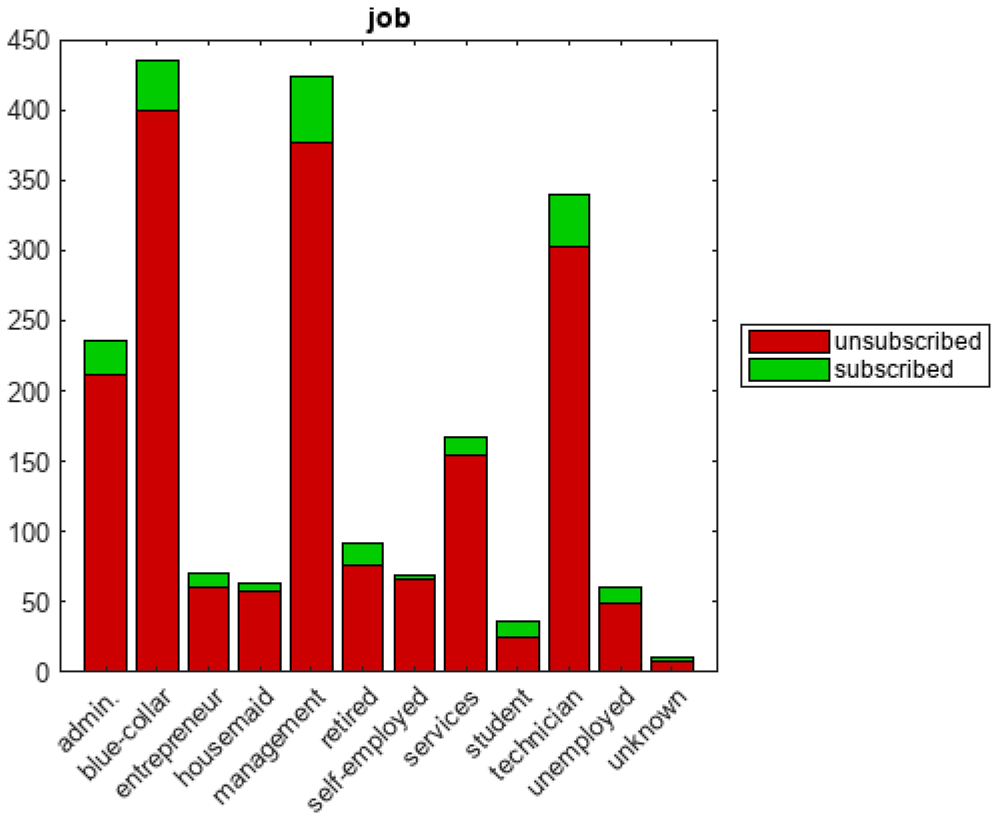
```
subscribed = training_set(training_set.subscribed == "yes",:);
unsubscribed = training_set(training_set.subscribed == "no",:);
```

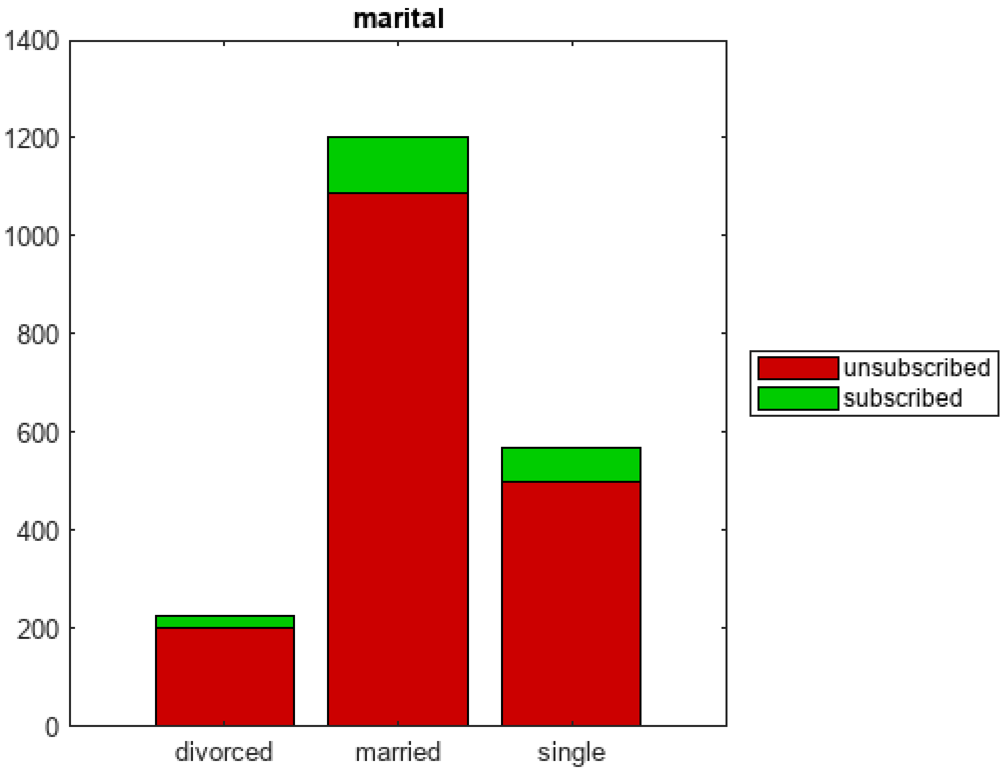
Histograms with category info

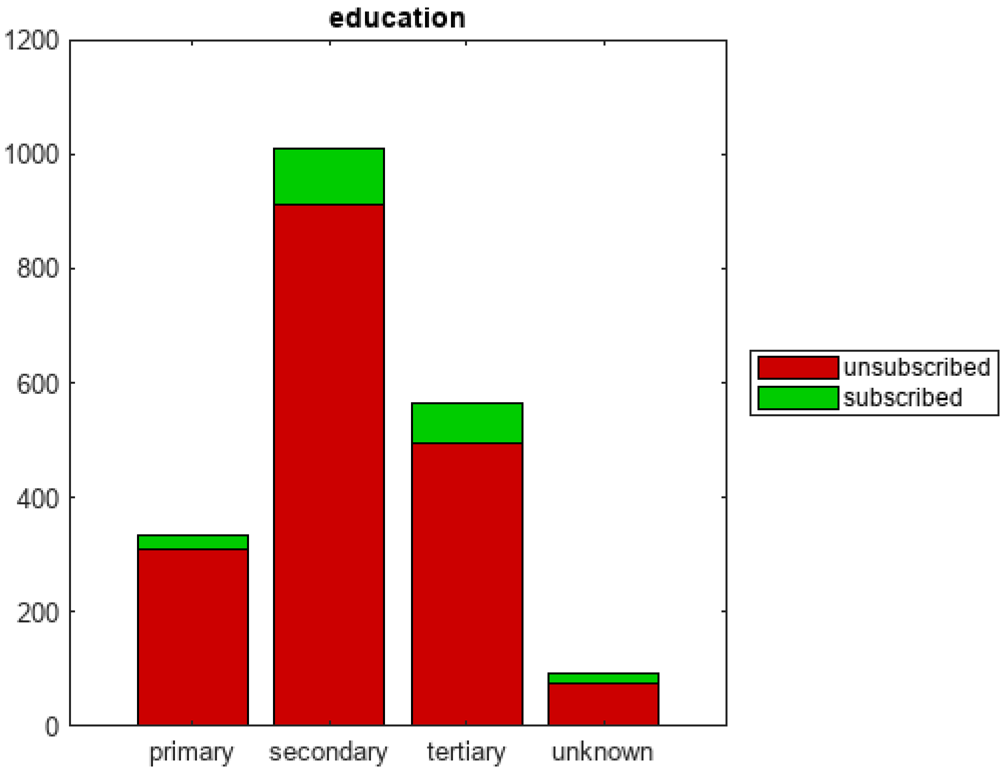
```
nbins = 25;

for col = 1: width(training_set)
```

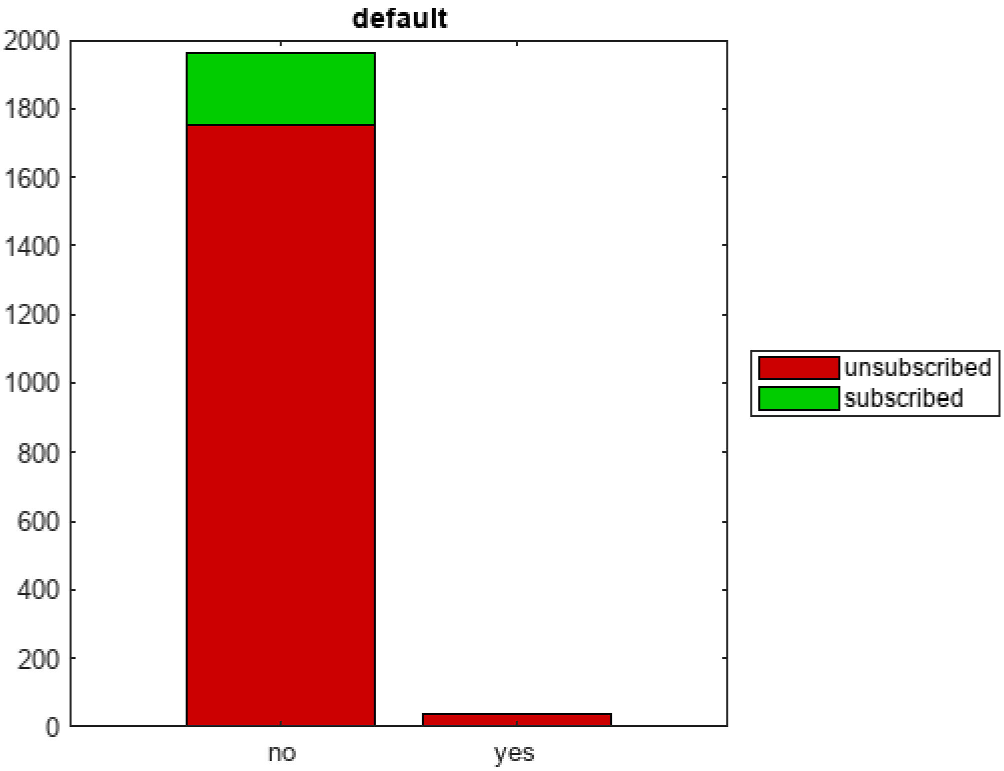
```
    figure

    if iscategorical(table2array(training_set(:,col)))
        Y(1,:) = countcats( table2array(unsubscribed(:,col)) );
        Y(2,:) = countcats( table2array(  subscribed(:,col)) );

        ba = bar(categorical(categories(table2array(training_set(:,col)))), ...
                 Y', 'stacked', 'FaceColor','flat');
        ba(1).CData = [0.8 0   0];
        ba(2).CData = [0   0.8 0];
        clear Y
    else
        hist_edges = linspace(min(table2array(training_set(:,col))), ...
                              max(table2array(training_set(:,col))), nbins+1);
        plot_edges = linspace(hist_edges(2)/2, (hist_edges(end-1)+hist_edges(end))/2, nbins);

        X(1,:) = histcounts( table2array(unsubscribed(:,col)), hist_edges);
        X(2,:) = histcounts( table2array(  subscribed(:,col)), hist_edges);

        ba = bar(plot_edges, X', 'stacked', 'FaceColor','flat');
        ba(1).CData = [0.8 0   0];
        ba(2).CData = [0   0.8 0];
    end

    title(training_set.Properties.VariableNames{col})
    if col == 5
        title(' default ')
    end
    legend('unsubscribed','subscribed','Location','eastoutside')
%     saveas(gcf,strcat('figures/Hist_training_', test_set.Properties.VariableNames{col}, '.png
end
```

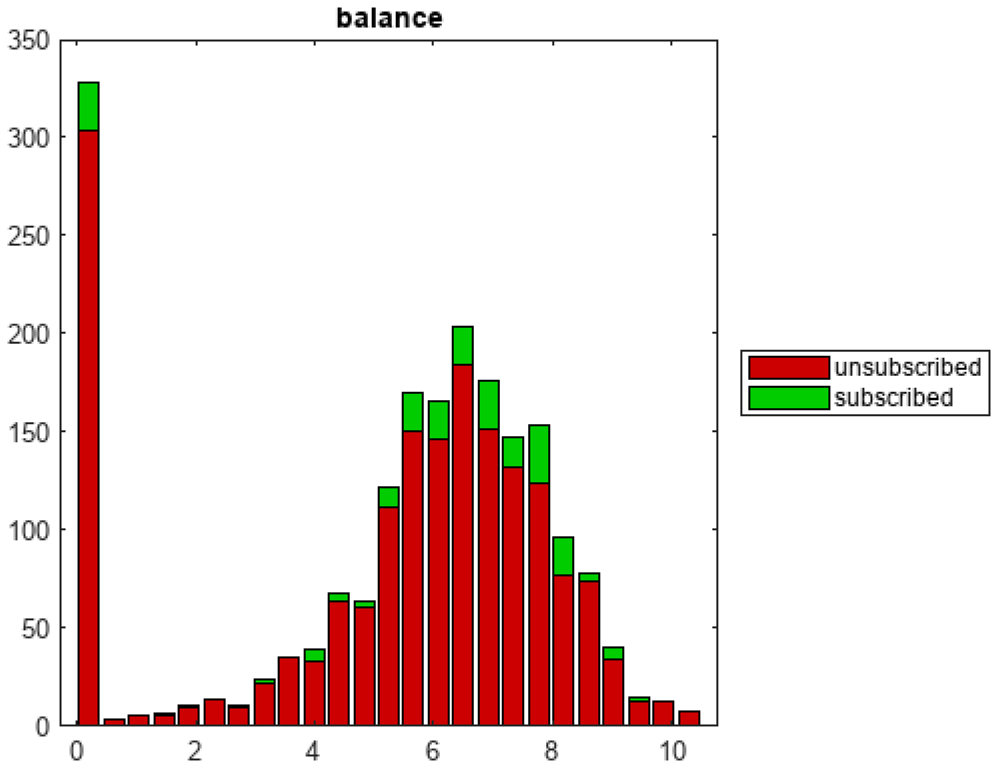

age
300
250
200
150
100
50
0
20
40
60
80
🟥 unsubscribed
🟩 subscribed

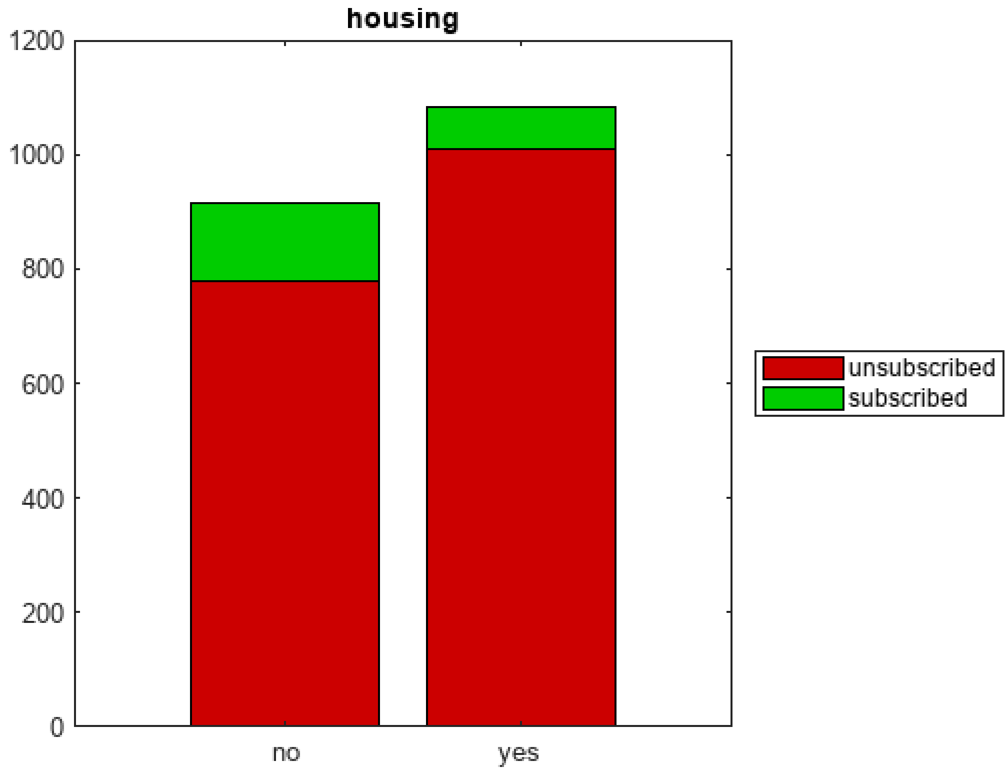

job
450
400
350
300
250
200
150
100
50
0
admin.
blue-collar
entrepreneur
housemaid
management
retired
self-employed
services
student
technician
unemployed
unknown
🟥 unsubscribed
🟩 subscribed

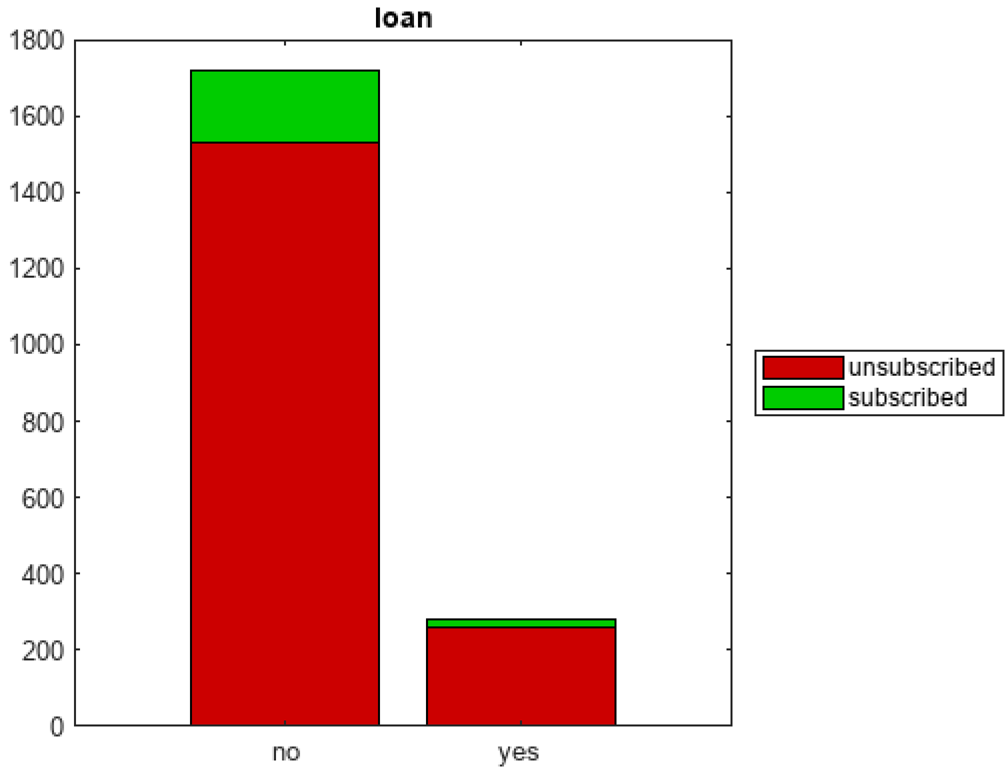

marital
1400
1200
1000
800
600
400
200
0
divorced
married
single
unsubscribed
subscribed

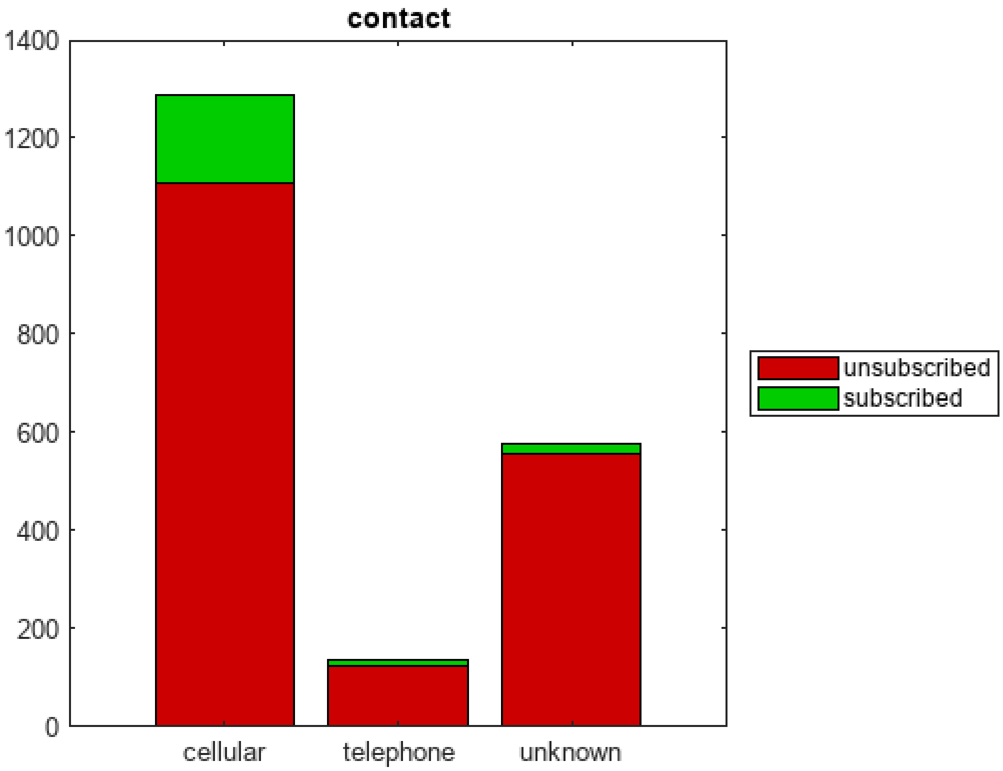

education
1200
1000
800
600
400
200
0
primary
secondary
tertiary
unknown
unsubscribed
subscribed

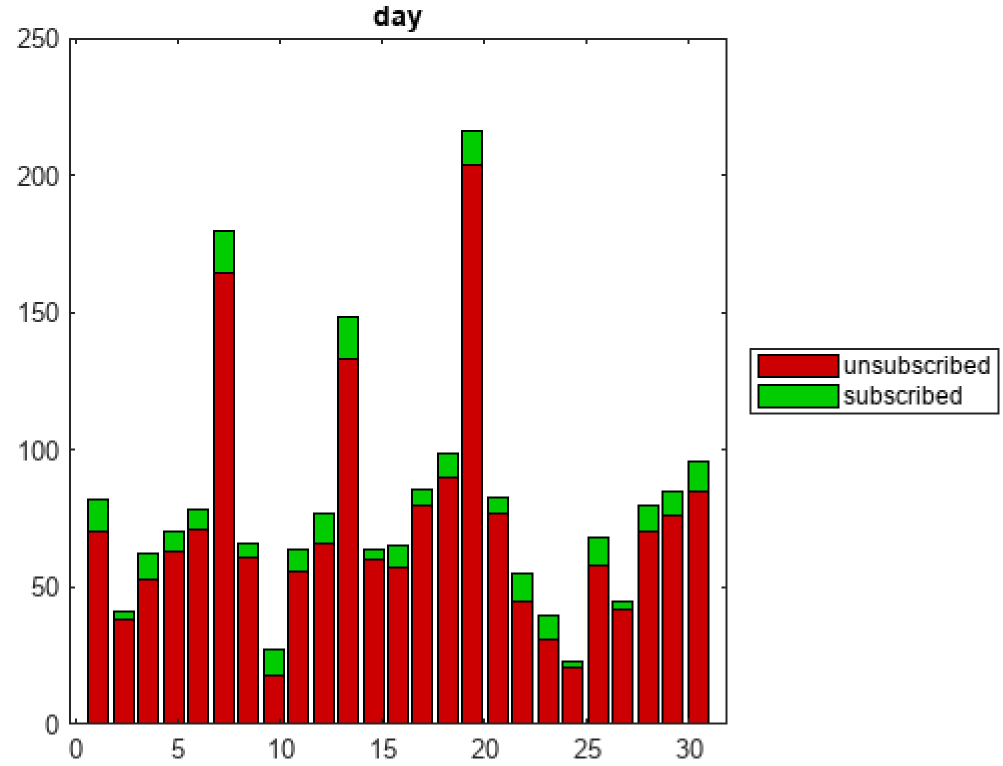

default
2000
1800
1600
1400
1200
1000
800
600
400
200
0
no
yes
🟥 unsubscribed
🟩 subscribed

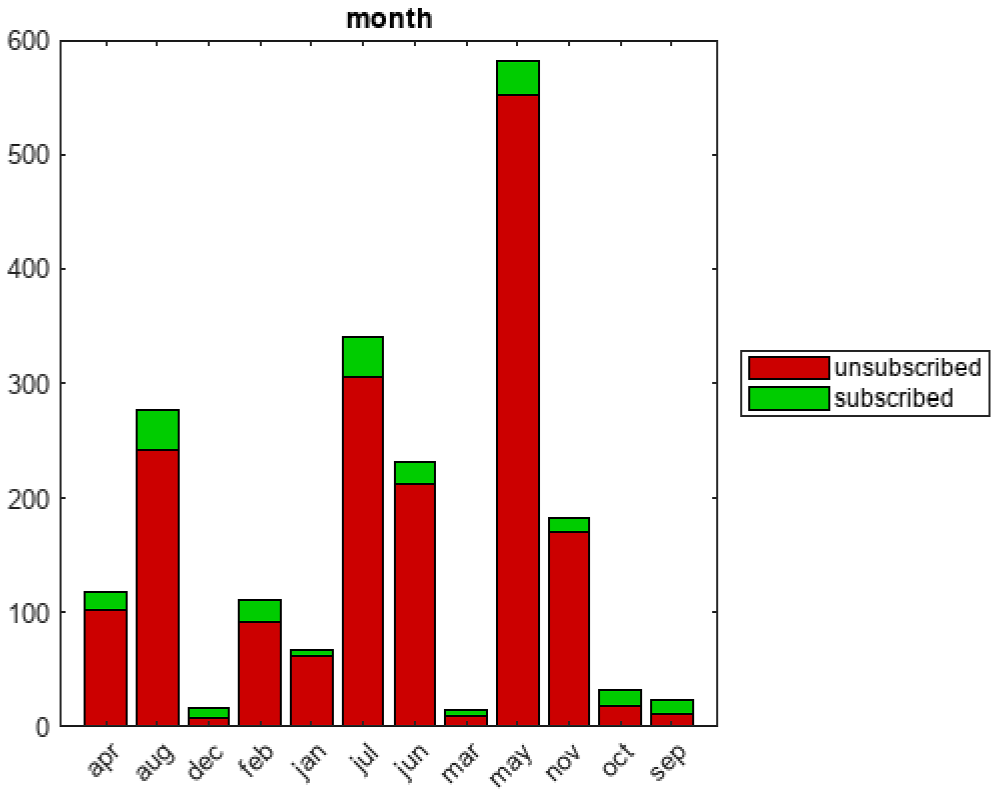

balance
350
300
250
200
150
100
50
0
0
2
4
6
8
10
🟥 unsubscribed
🟩 subscribed

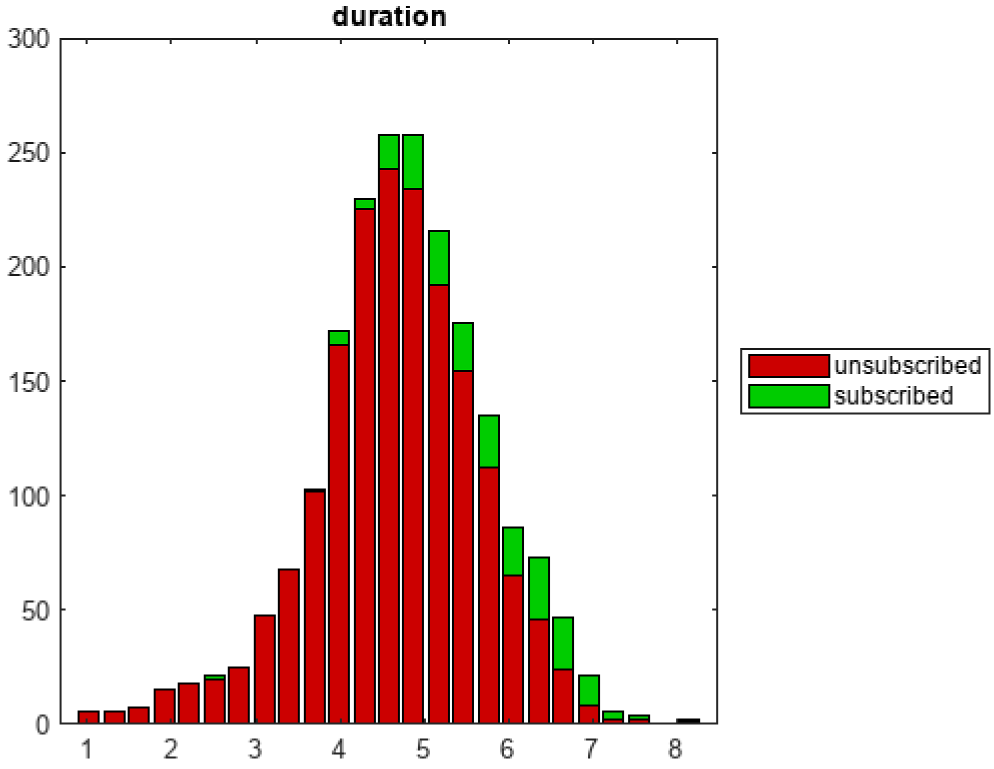

housing
1200
1000
800
600
400
200
0
no
yes
🟥 unsubscribed
🟩 subscribed

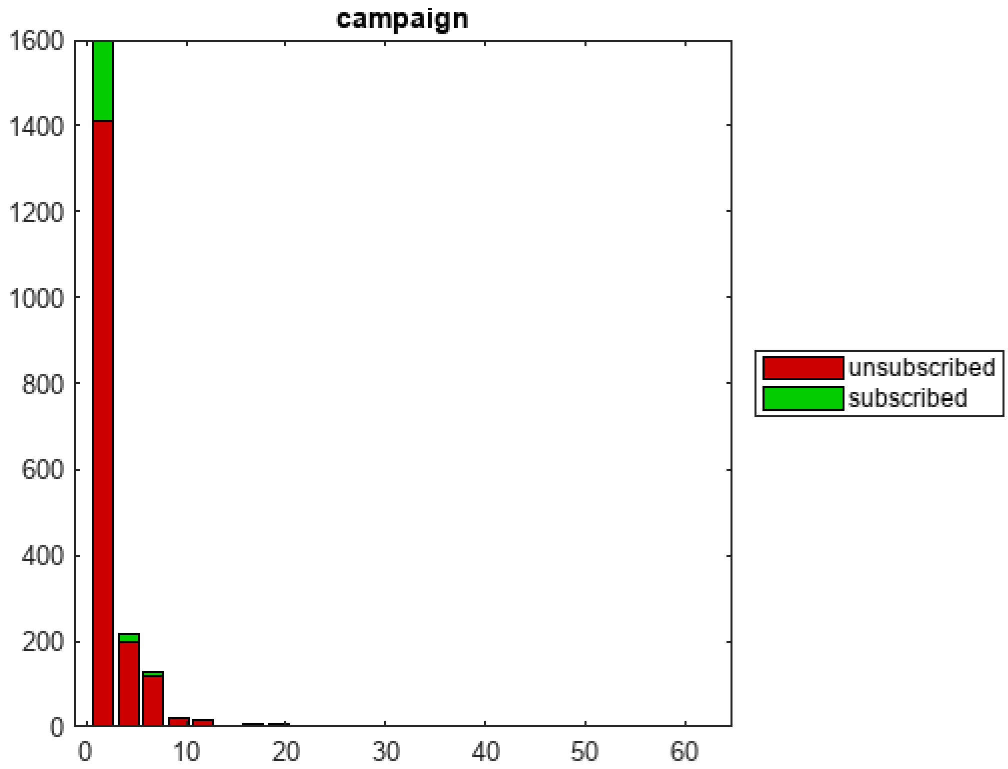

loan
1800
1600
1400
1200
1000
800
600
400
200
0
no
yes
🟥 unsubscribed
🟩 subscribed

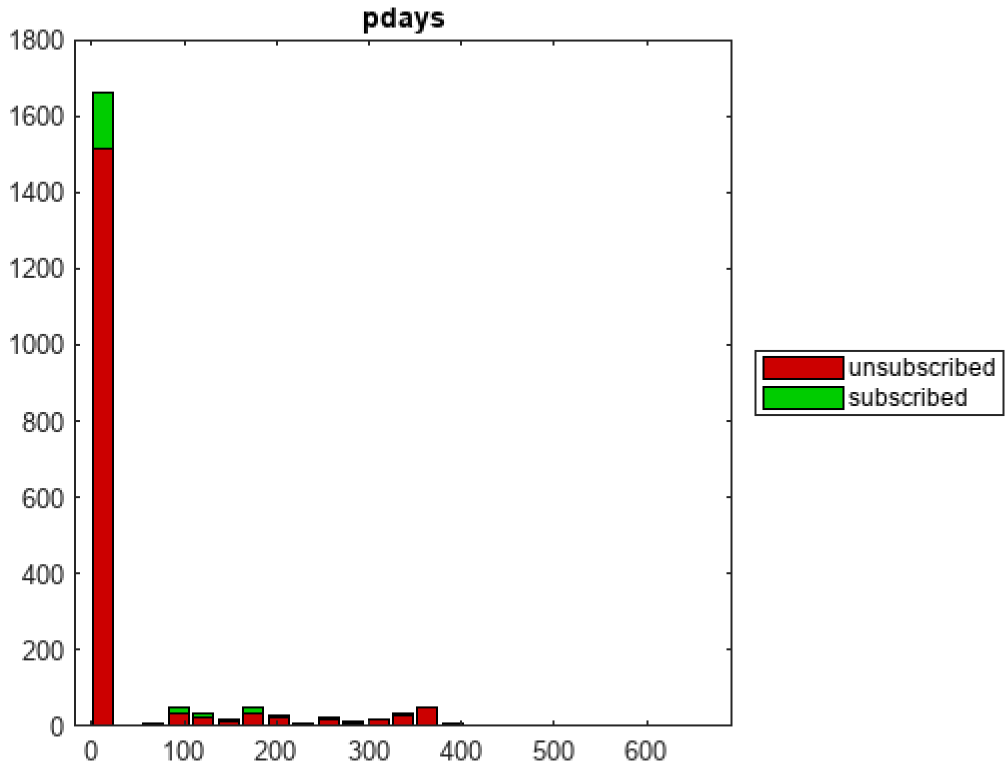

contact
1400
1200
1000
800
600
400
200
0
cellular
telephone
unknown
unsubscribed
subscribed

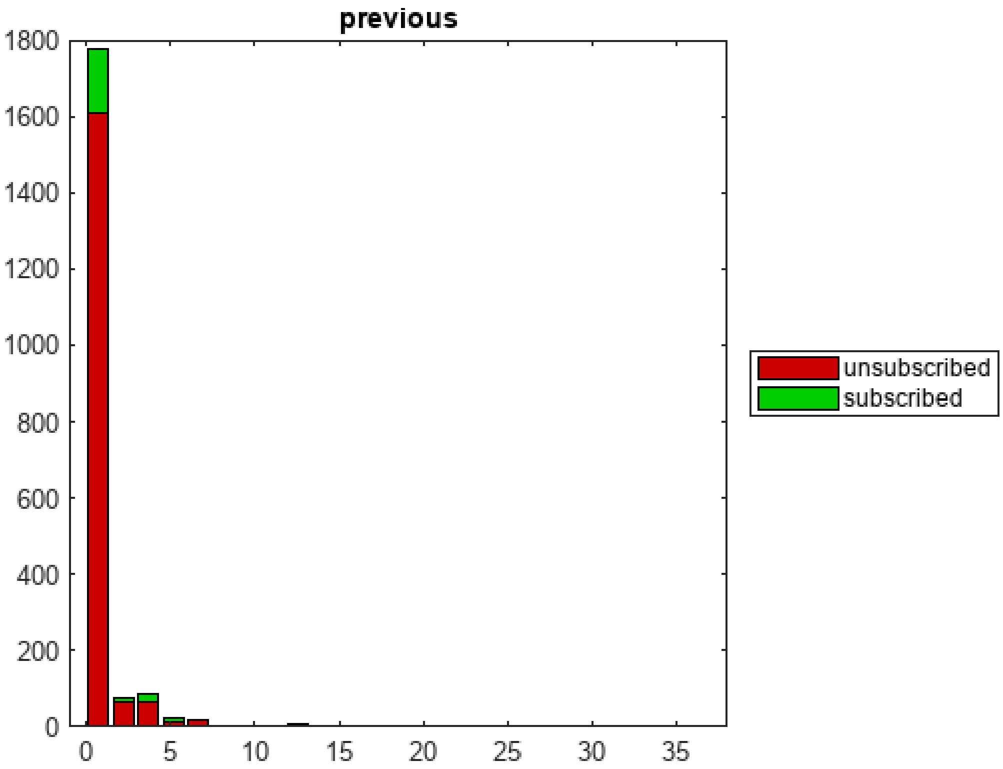

day
250
200
150
100
50
0
0
5
10
15
20
25
30
unsubscribed
subscribed

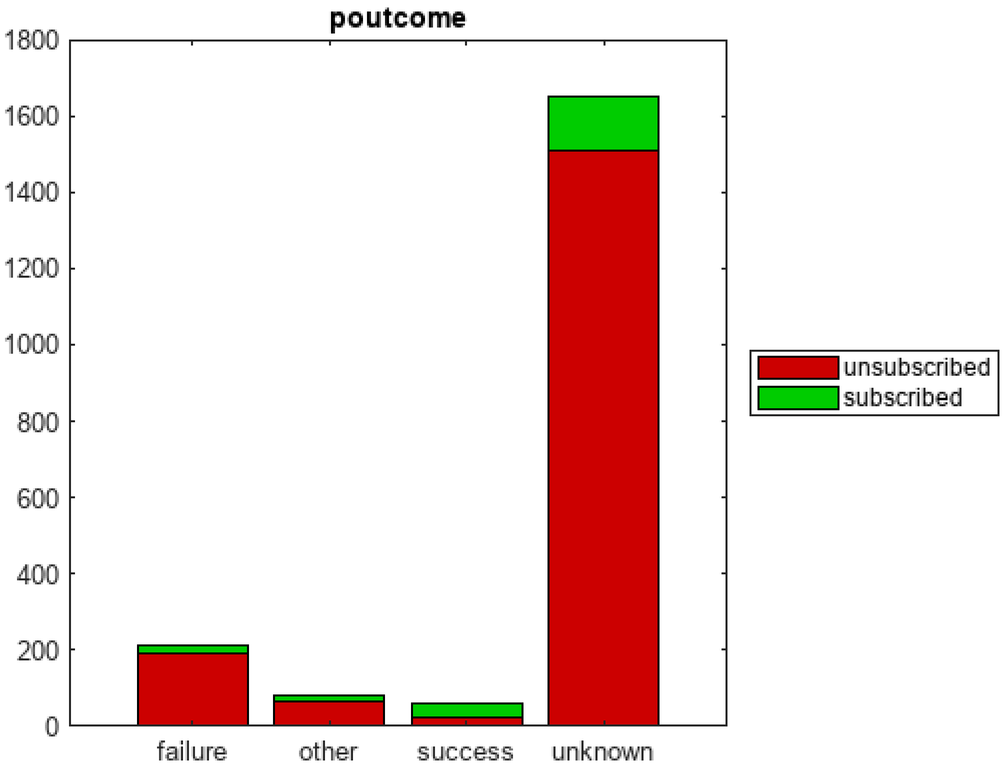

month
600
500
400
300
200
100
0
apr
aug
dec
feb
jan
jul
jun
mar
may
nov
oct
sep
unsubscribed
subscribed

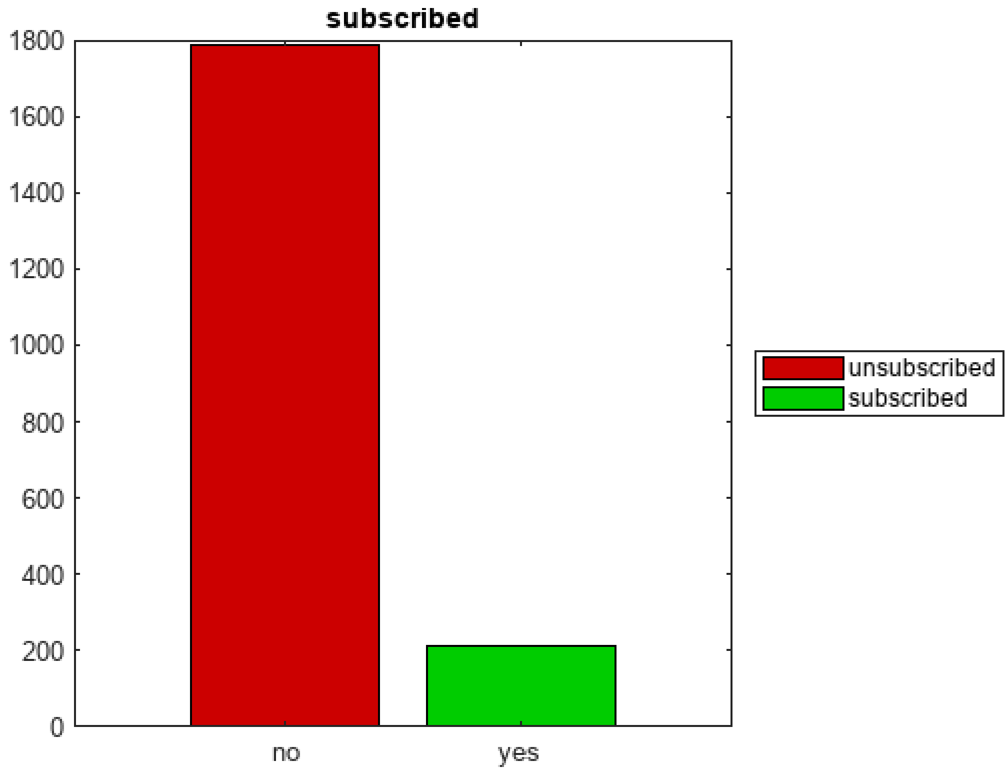

duration
300
250
200
150
100
50
0
1
2
3
4
5
6
7
8
unsubscribed
subscribed

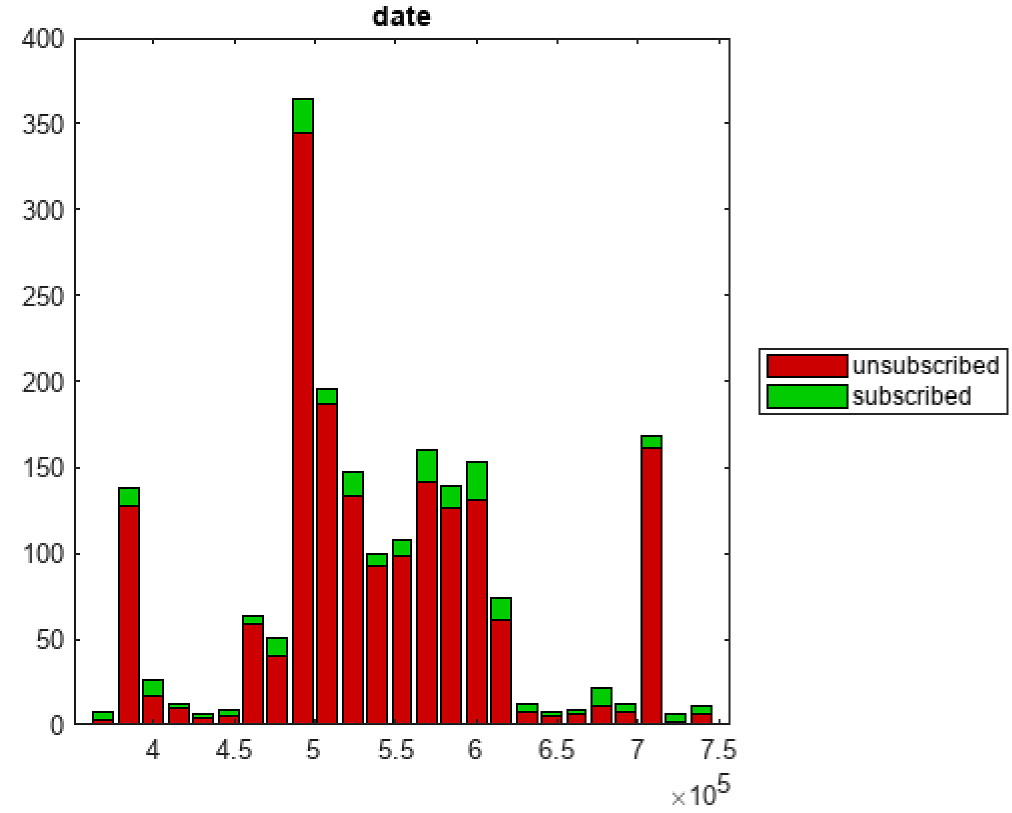

campaign
1600
1400
1200
1000
800
600
400
200
0
0
10
20
30
40
50
60
unsubscribed
subscribed


pdays
1800
1600
1400
1200
1000
800
600
400
200
0
0
100
200
300
400
500
600
unsubscribed
subscribed


previous
1800
1600
1400
1200
1000
800
600
400
200
0
0
5
10
15
20
25
30
35
🟥 unsubscribed
🟩 subscribed


poutcome
1800
1600
1400
1200
1000
800
600
400
200
0
failure
other
success
unknown
🟥 unsubscribed
🟩 subscribed

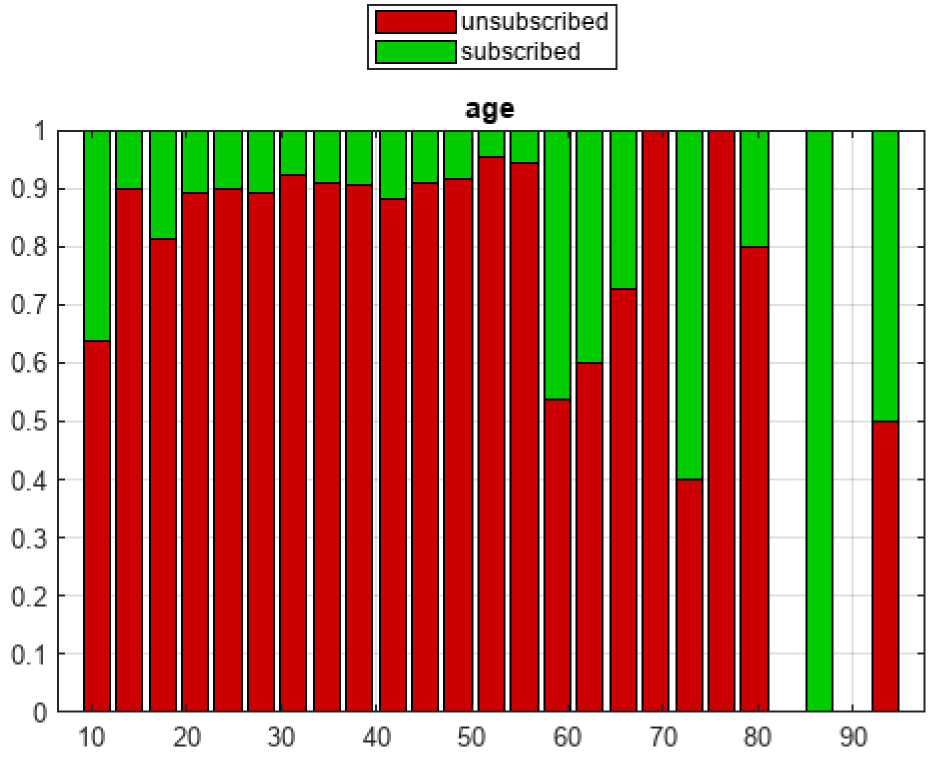


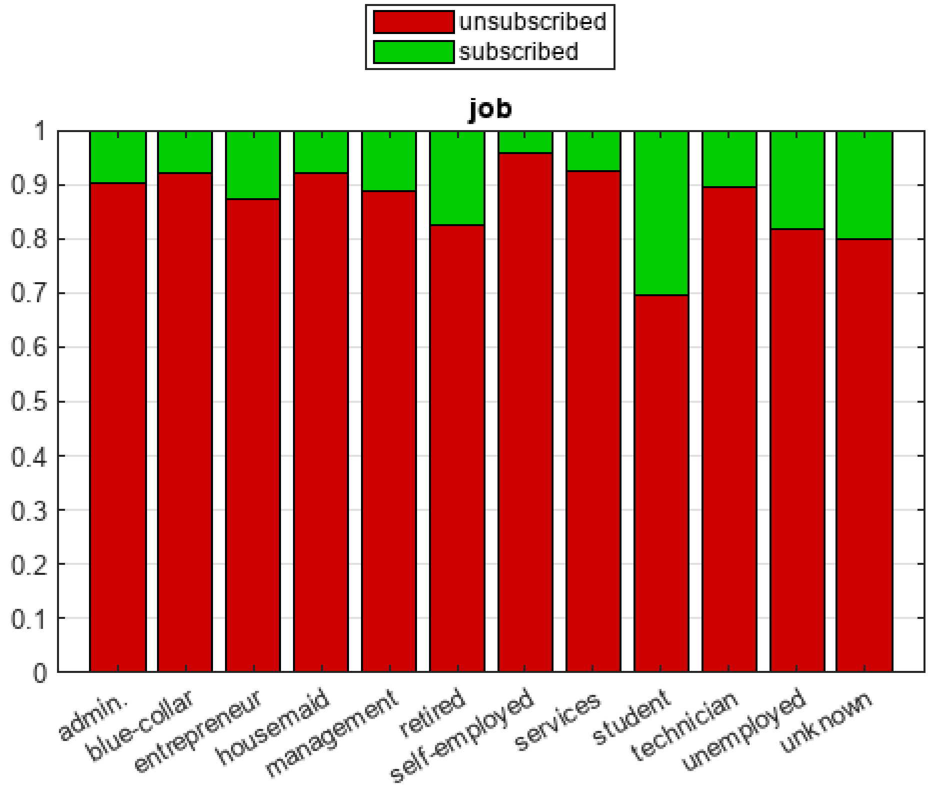


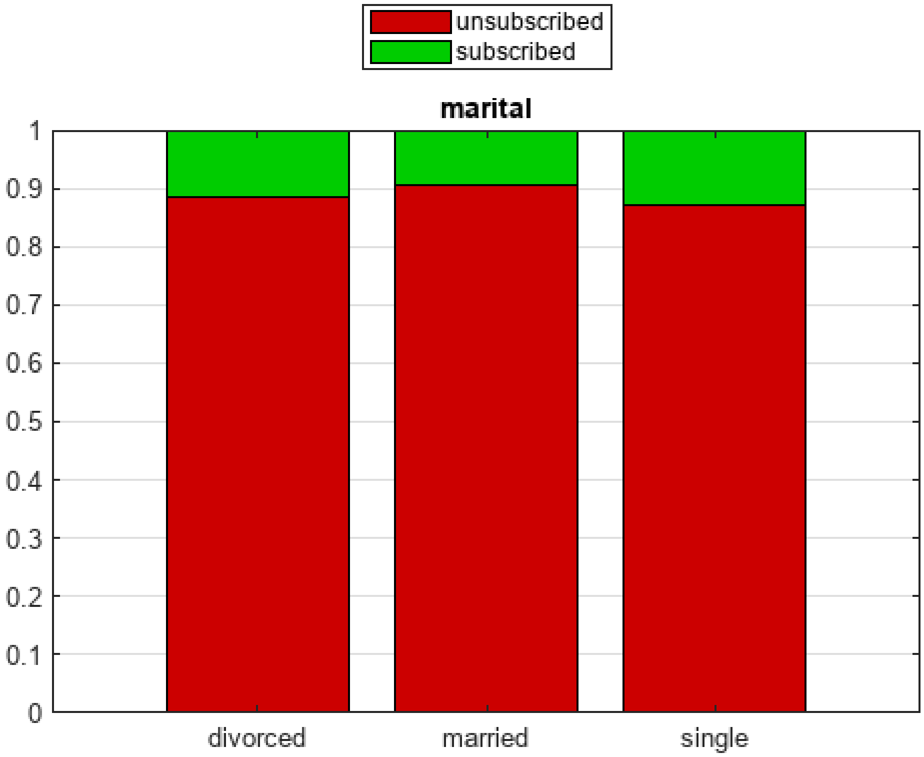
% of Subscribed

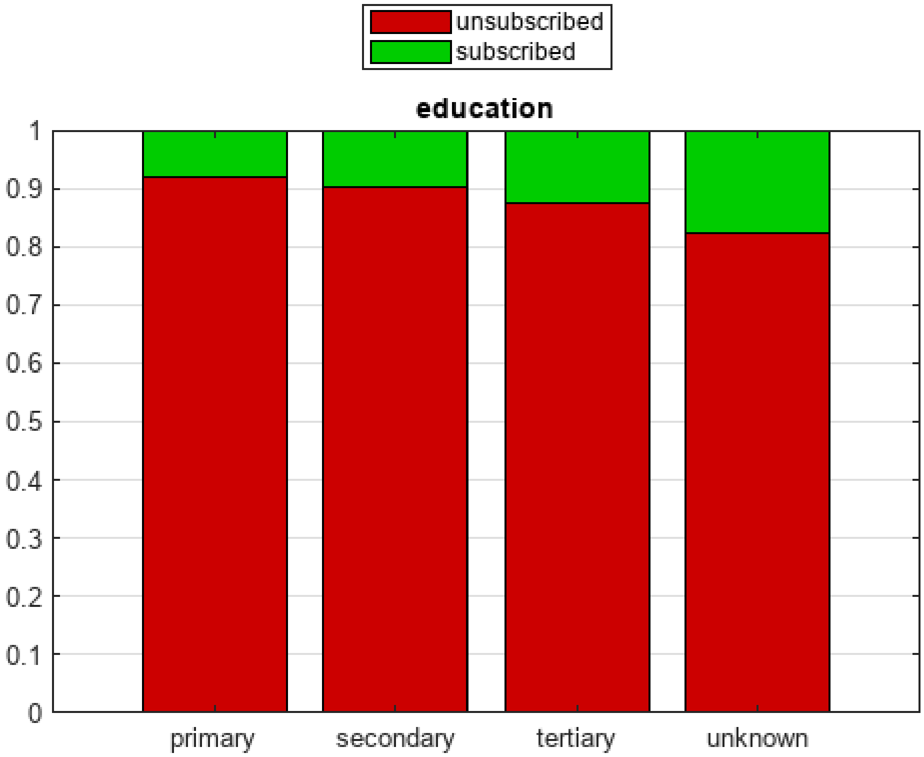
```
nbins = 25;
```

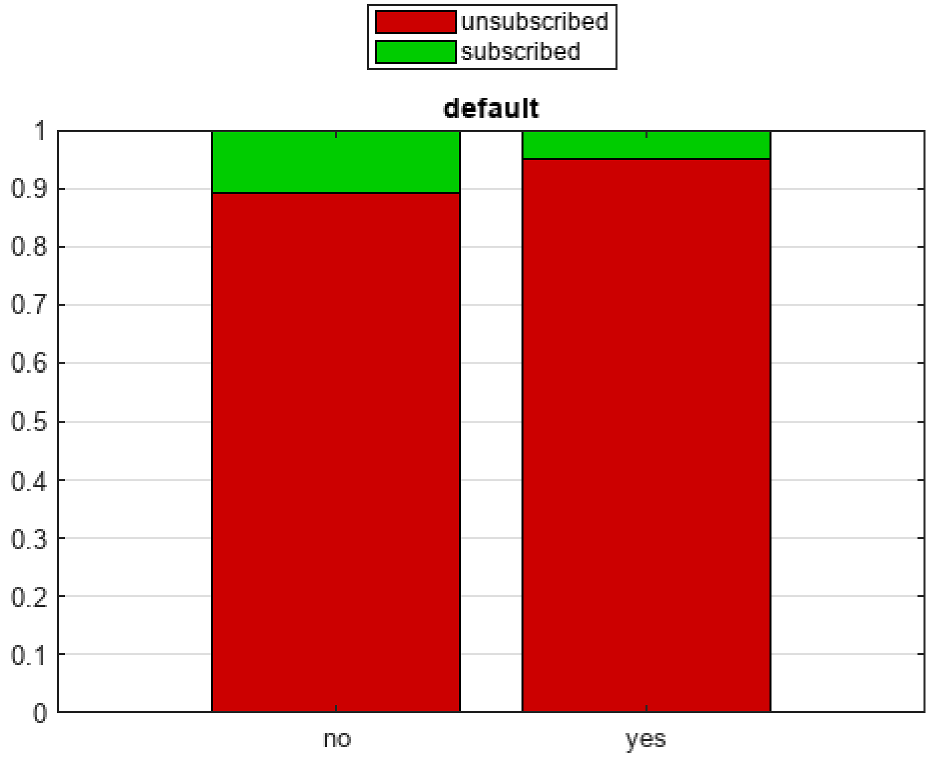
```
for col = 1: width(training_set)
    figure

    if iscategorical(table2array(training_set(:,col)))
        Y(1,:) = countcats( table2array(unsubscribed(:,col)) ) ./ ...
                 countcats( table2array(training_set(:,col)) );
        Y(2,:) = countcats( table2array(  subscribed(:,col)) ) ./ ...
                 countcats( table2array(training_set(:,col)) );

        ba = bar(categorical(categories(table2array(training_set(:,col)))), ...
                 Y', 'stacked', 'FaceColor','flat');
        ba(1).CData = [0.8 0   0];
        ba(2).CData = [0   0.8 0];
        clear Y
    else
        hist_edges = linspace(min(table2array(training_set(:,col))), ...
                              max(table2array(training_set(:,col))), nbins+1);
        plot_edges = linspace(hist_edges(2)/2, (hist_edges(end-1)+hist_edges(end))/2, nbins);

        X(1,:) = histcounts( table2array(unsubscribed(:,col)), hist_edges) ./ ...
                 histcounts( table2array(training_set(:,col)), hist_edges);
        X(2,:) = histcounts( table2array(  subscribed(:,col)), hist_edges) ./ ...
                 histcounts( table2array(training_set(:,col)), hist_edges);

        ba = bar(plot_edges, X', 'stacked', 'FaceColor','flat');
        ba(1).CData = [0.8 0   0];
        ba(2).CData = [0   0.8 0];
    end

    title(training_set.Properties.VariableNames{col})
    if col == 5
        title(' default ')
    end
    legend('unsubscribed','subscribed','Location','northoutside')
    ylim([0 1])
    grid()
%     saveas(gcf,strcat('figures/Proportion_', test_set.Properties.VariableNames{col}, '.png'))
end
```

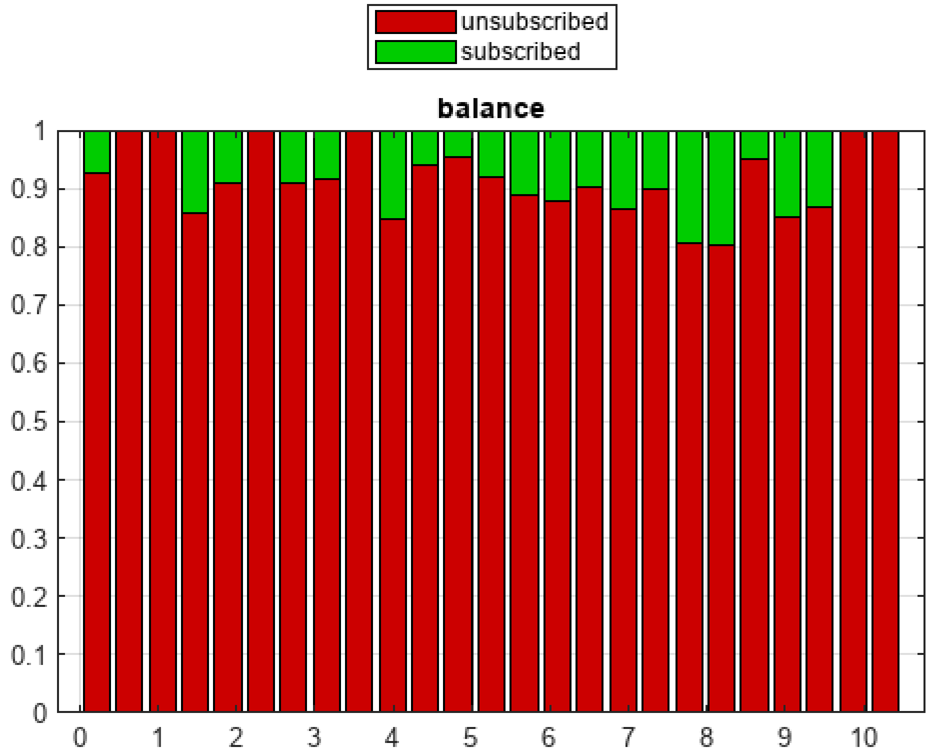

unsubscribed
subscribed
age
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
10
20
30
40
50
60
70
80
90

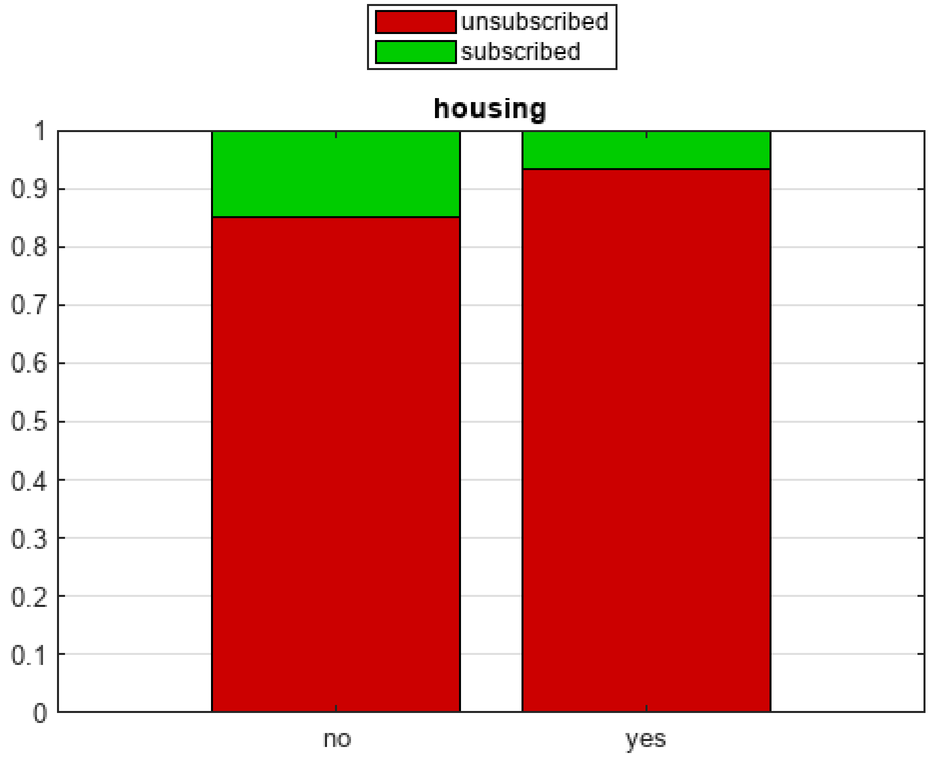

unsubscribed
subscribed
job
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
admin.
blue-collar
entrepreneur
housemaid
management
retired
self-employed
services
student
technician
unemployed
unknown

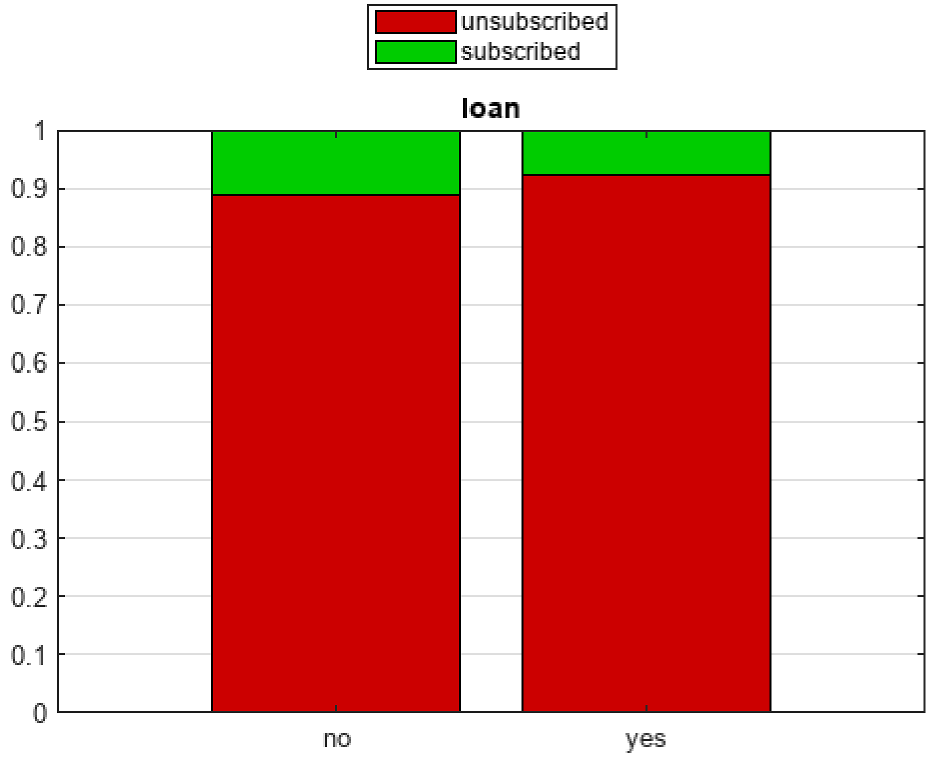

🟥 unsubscribed
🟩 subscribed
marital
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
divorced
married
single

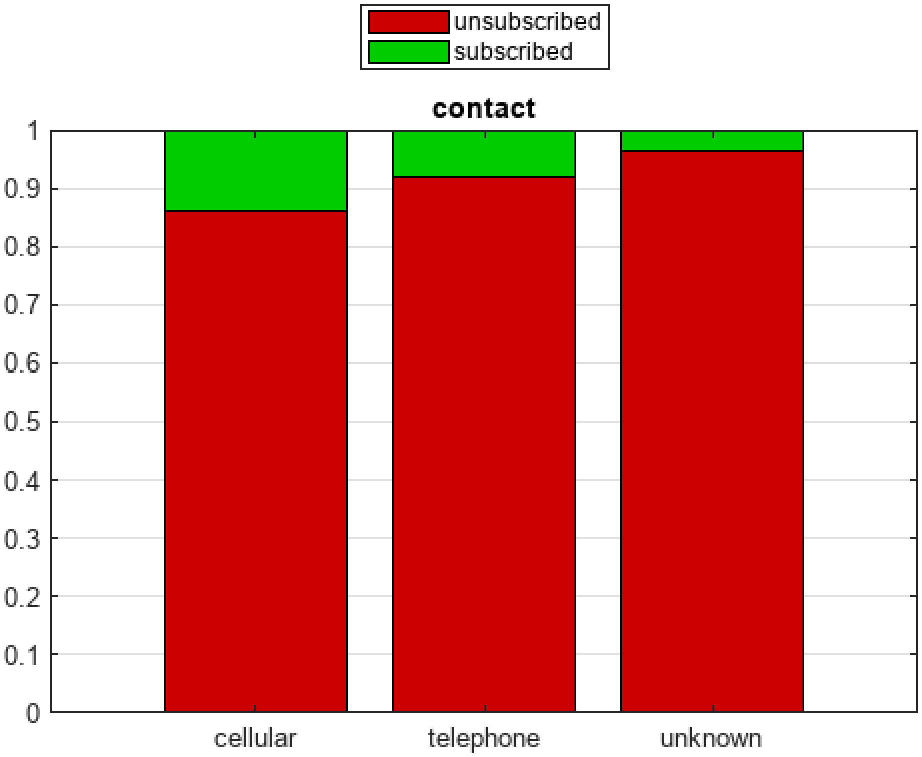

🟥 unsubscribed
🟩 subscribed
education
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
primary
secondary
tertiary
unknown

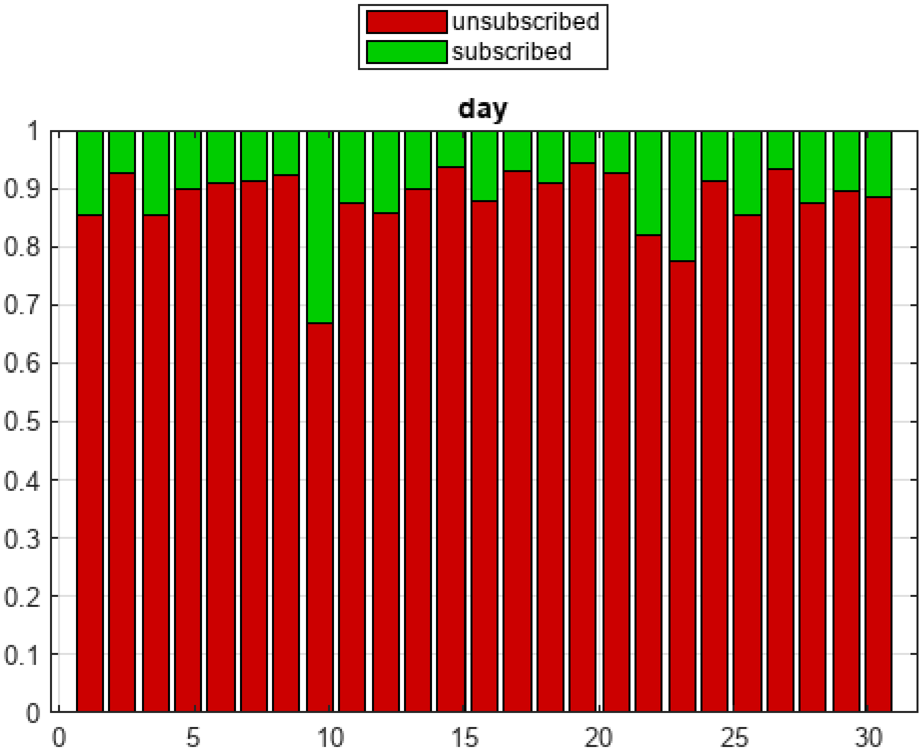

unsubscribed
subscribed
default
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
no
yes

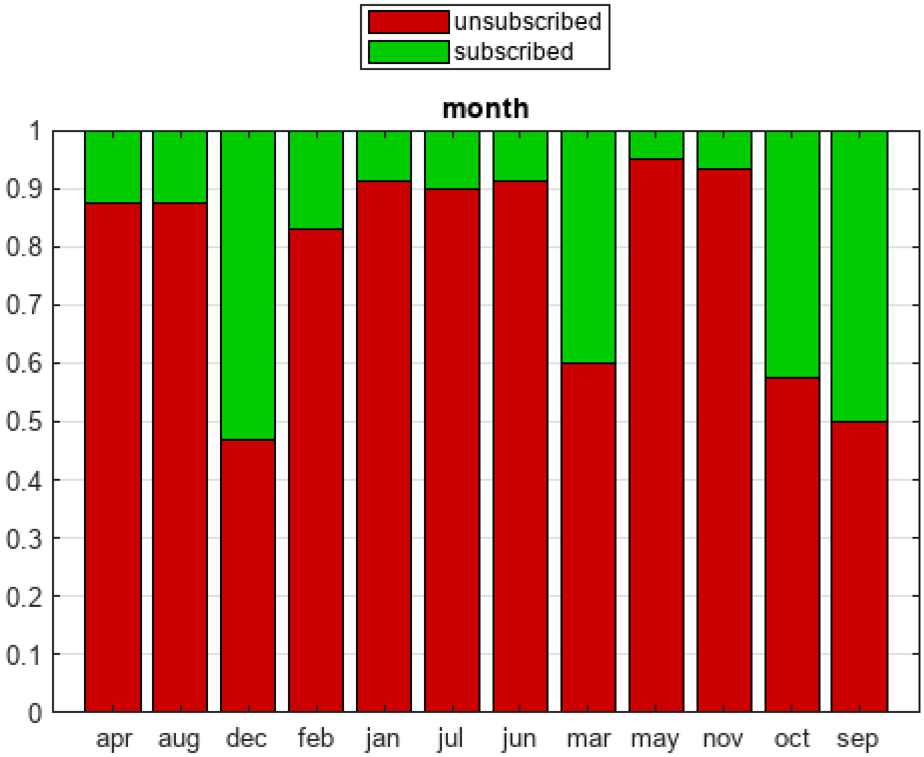

unsubscribed
subscribed
balance
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
1
2
3
4
5
6
7
8
9
10

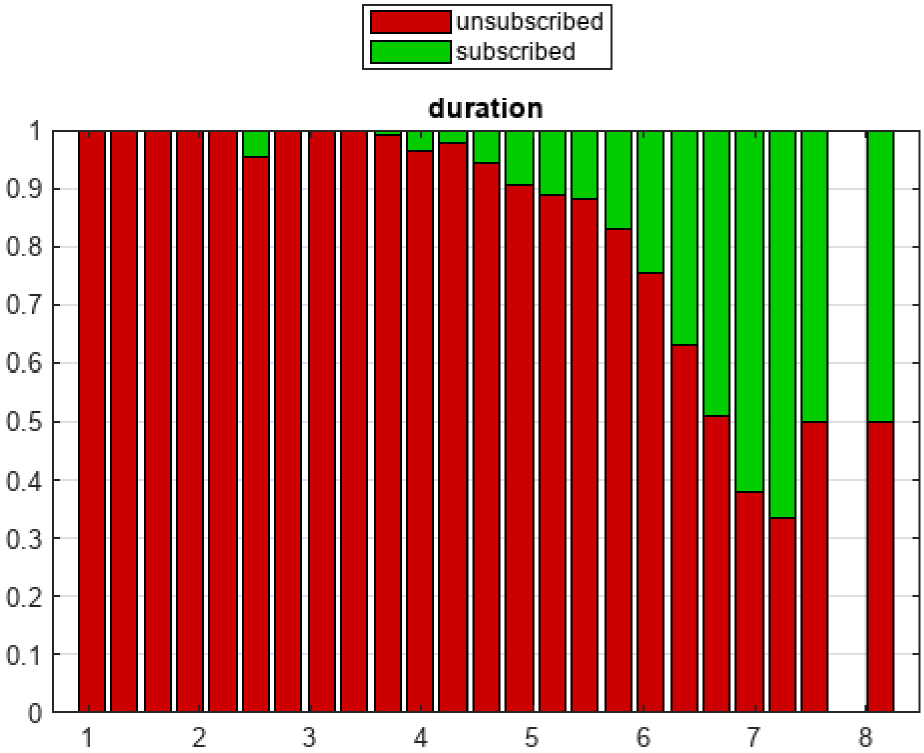

unsubscribed
subscribed
housing
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
no
yes

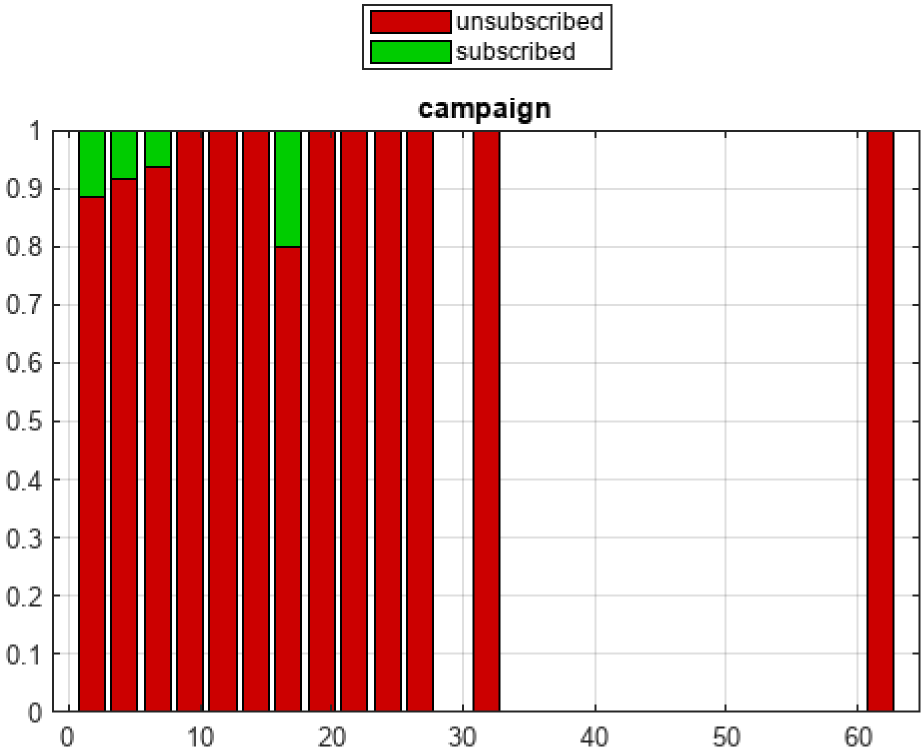

unsubscribed
subscribed
loan
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
no
yes

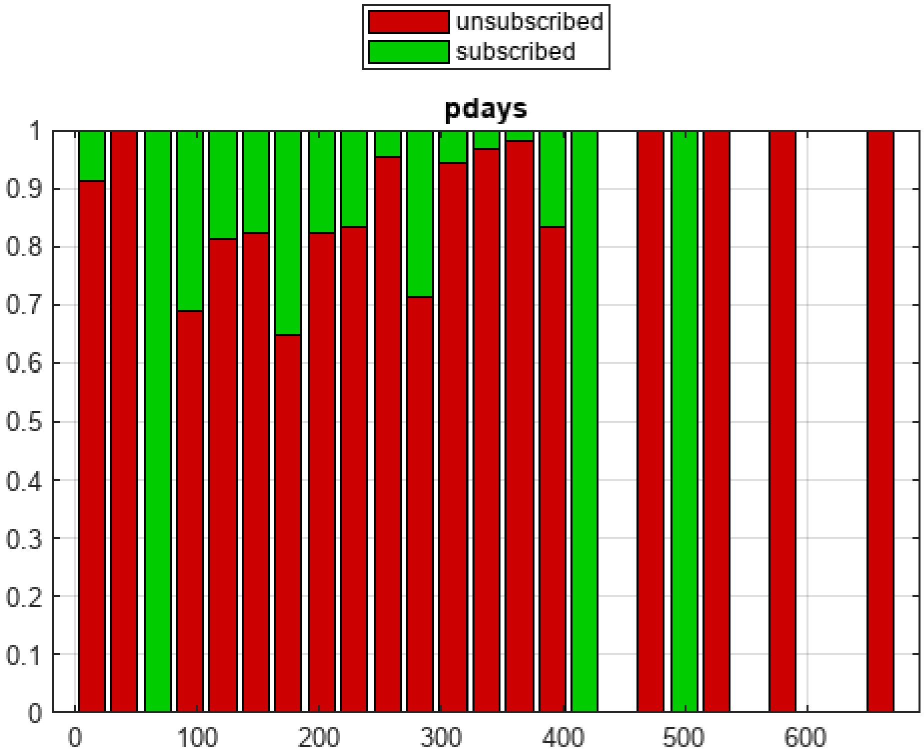

unsubscribed
subscribed
contact
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
cellular
telephone
unknown

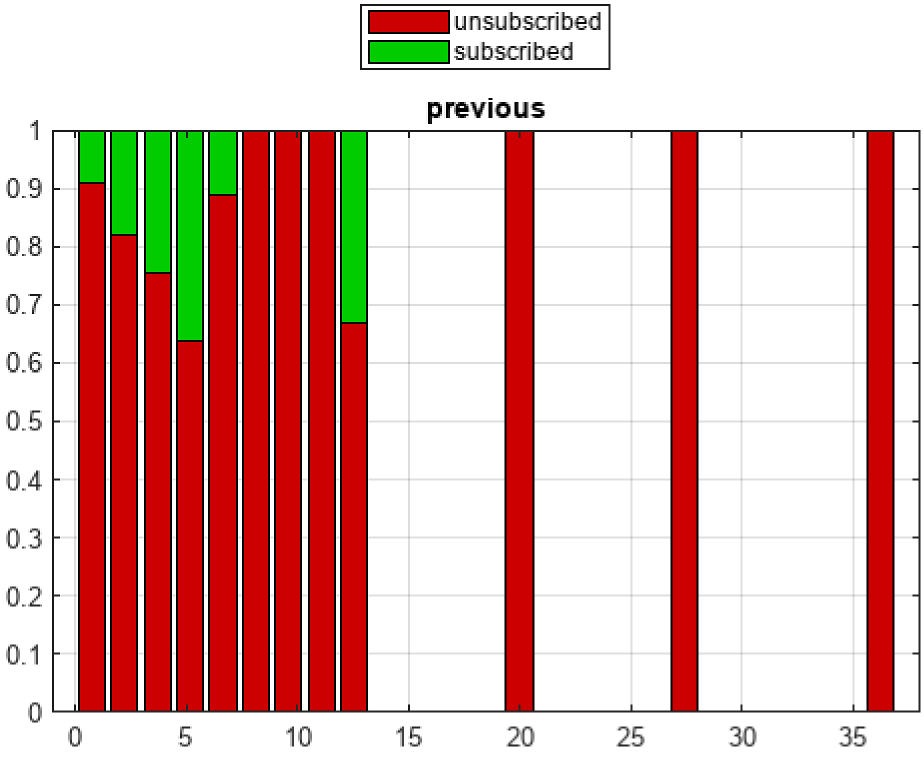

unsubscribed
subscribed
day
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
5
10
15
20
25
30

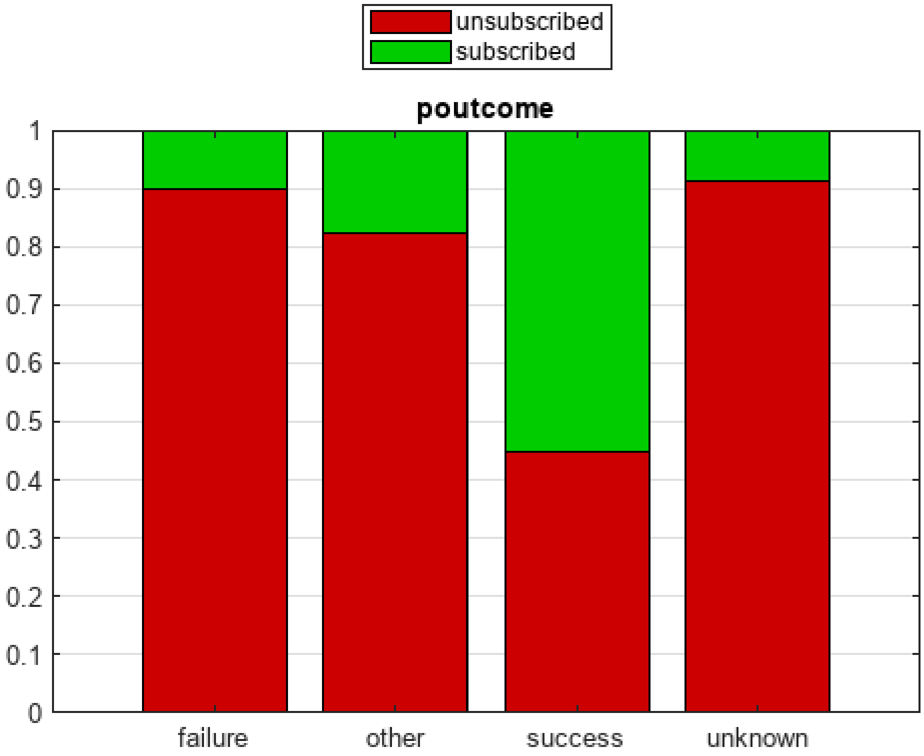

unsubscribed
subscribed
month
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
apr
aug
dec
feb
jan
jul
jun
mar
may
nov
oct
sep

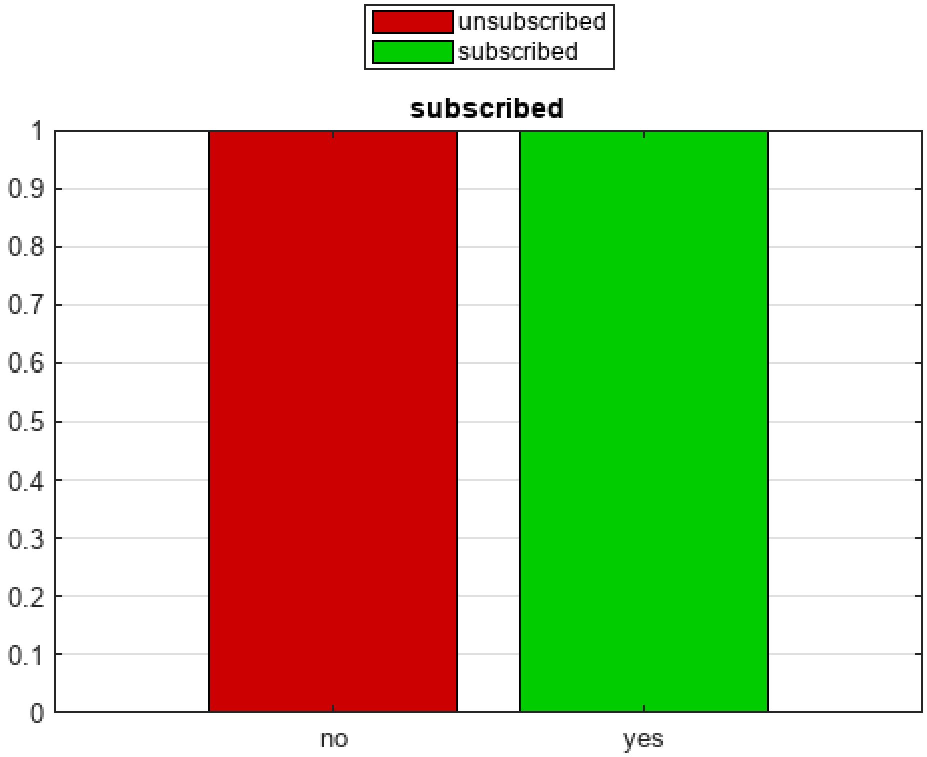

unsubscribed
subscribed
duration
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1
2
3
4
5
6
7
8

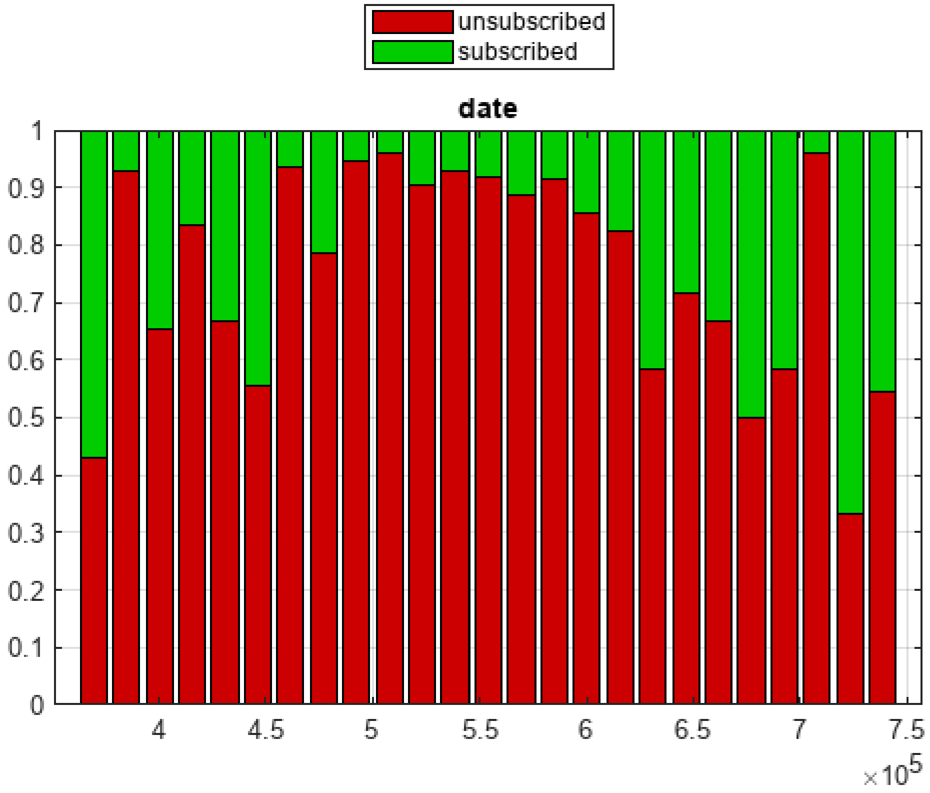

unsubscribed
subscribed
campaign
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
10
20
30
40
50
60


unsubscribed
subscribed
pdays
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
100
200
300
400
500
600


unsubscribed
subscribed
previous
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
5
10
15
20
25
30
35


unsubscribed
subscribed
poutcome
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
failure
other
success
unknown

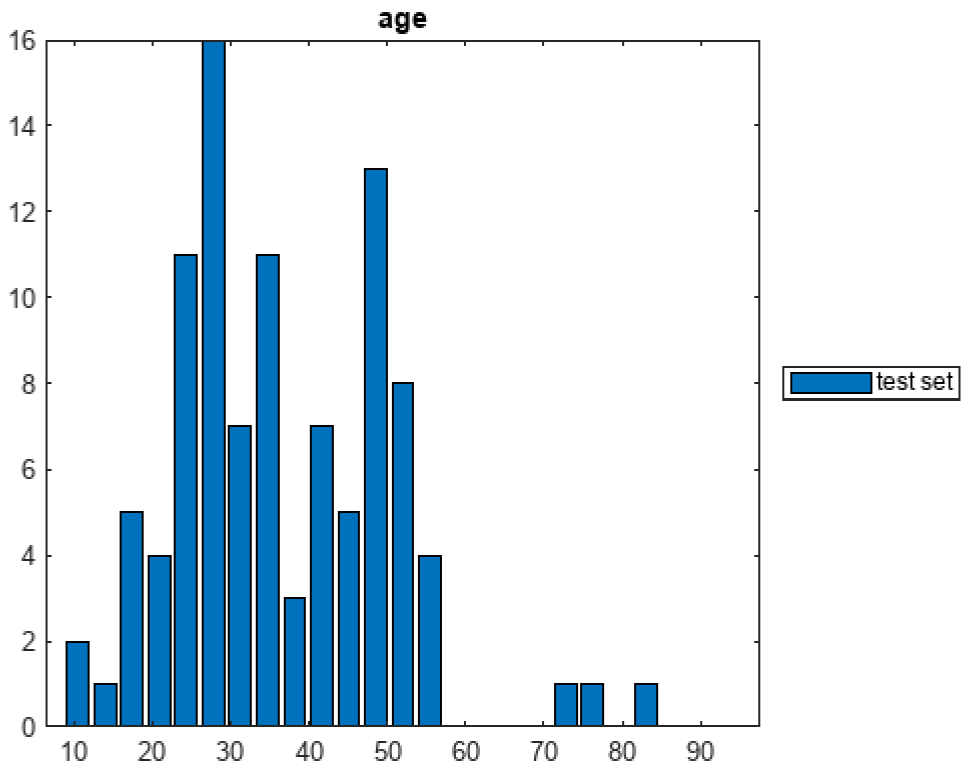


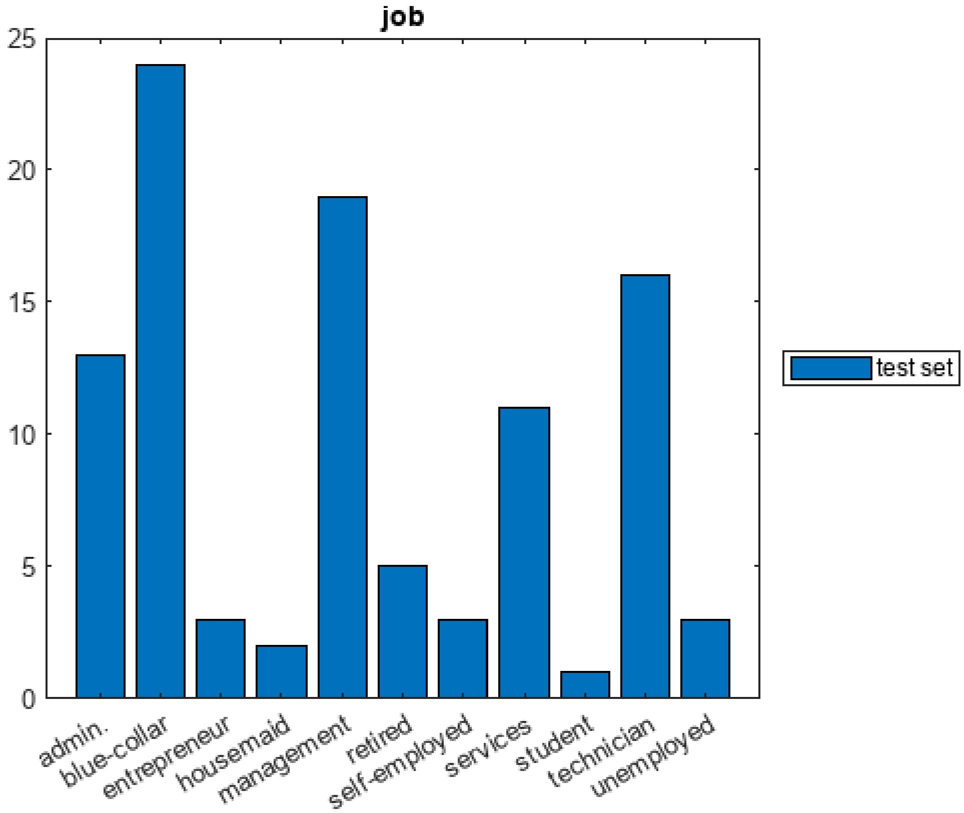


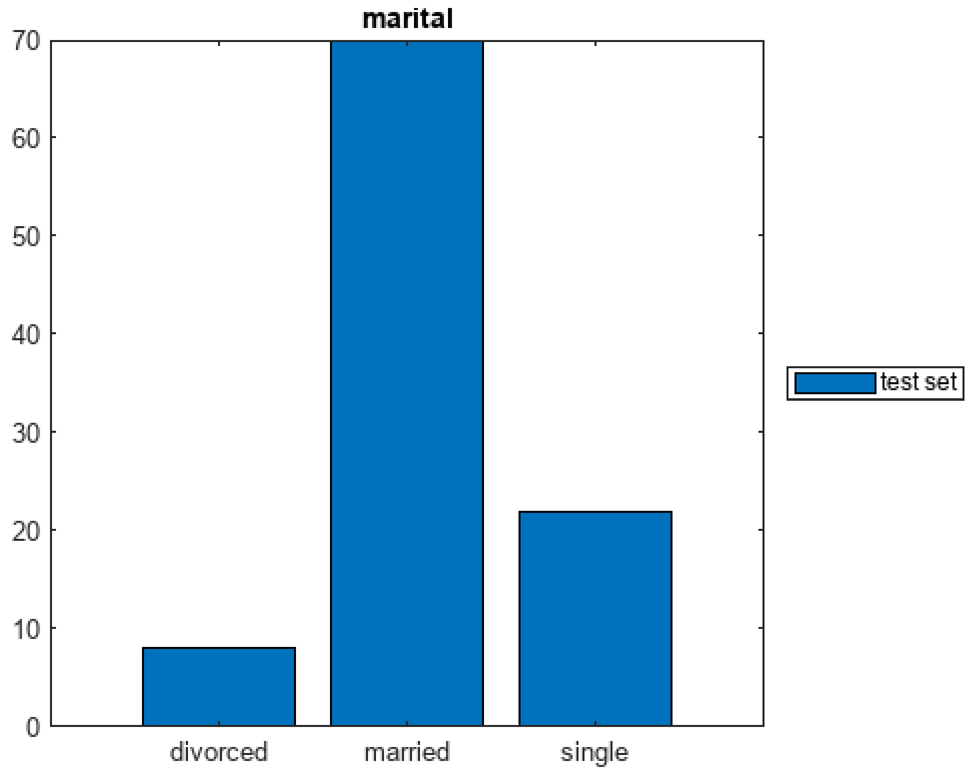
Histograms of test set

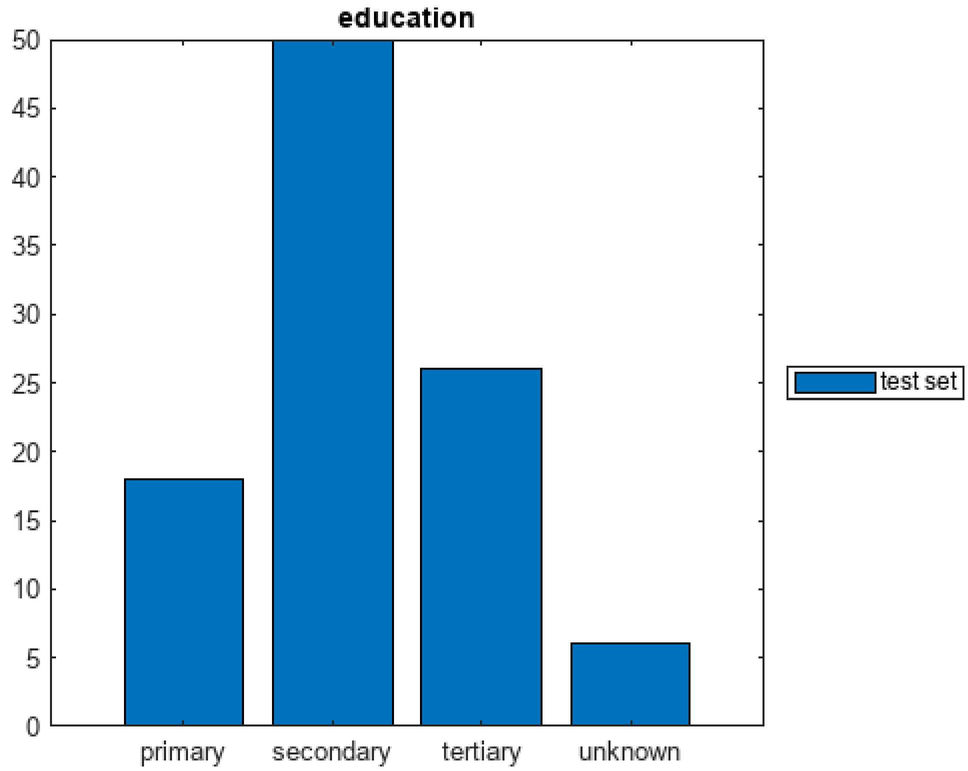
```
nbins = 25;
```

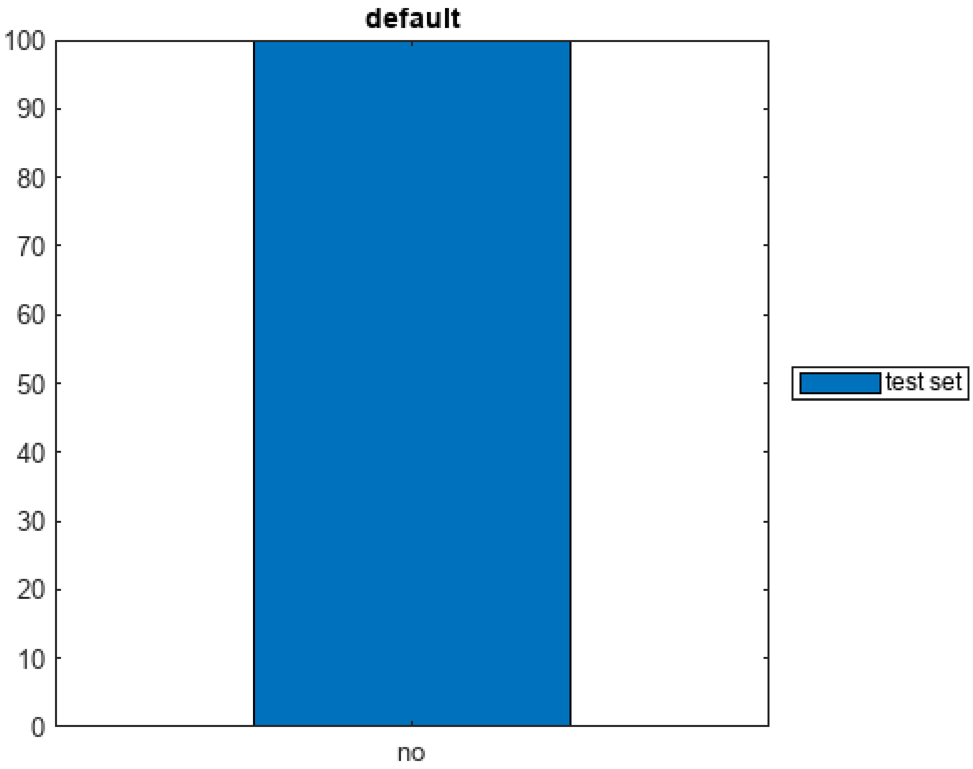
```
for col = 1: width(test_set)
    figure

    if iscategorical(table2array(test_set(:,col)))
        Y = countcats( table2array(test_set(:,col)) );

        ba = bar(categorical(categories(table2array(test_set(:,col)))), ...
                  Y', 'FaceColor','flat');
        clear Y
    else
        hist_edges = linspace(min(table2array(training_set(:,col))), ...
                              max(table2array(training_set(:,col))), nbins+1);
        plot_edges = linspace(hist_edges(2)/2, (hist_edges(end-1)+hist_edges(end))/2, nbins);

        X = histcounts( table2array(test_set(:,col)), hist_edges);

        ba = bar(plot_edges, X', 'FaceColor','flat');
    end

    title(test_set.Properties.VariableNames{col})
    if col == 5
        title(' default ')
    end
    legend('test set','Location','eastoutside')
%     saveas(gcf,strcat('figures/Hist_test_', test_set.Properties.VariableNames{col}, '.png') )
end
```

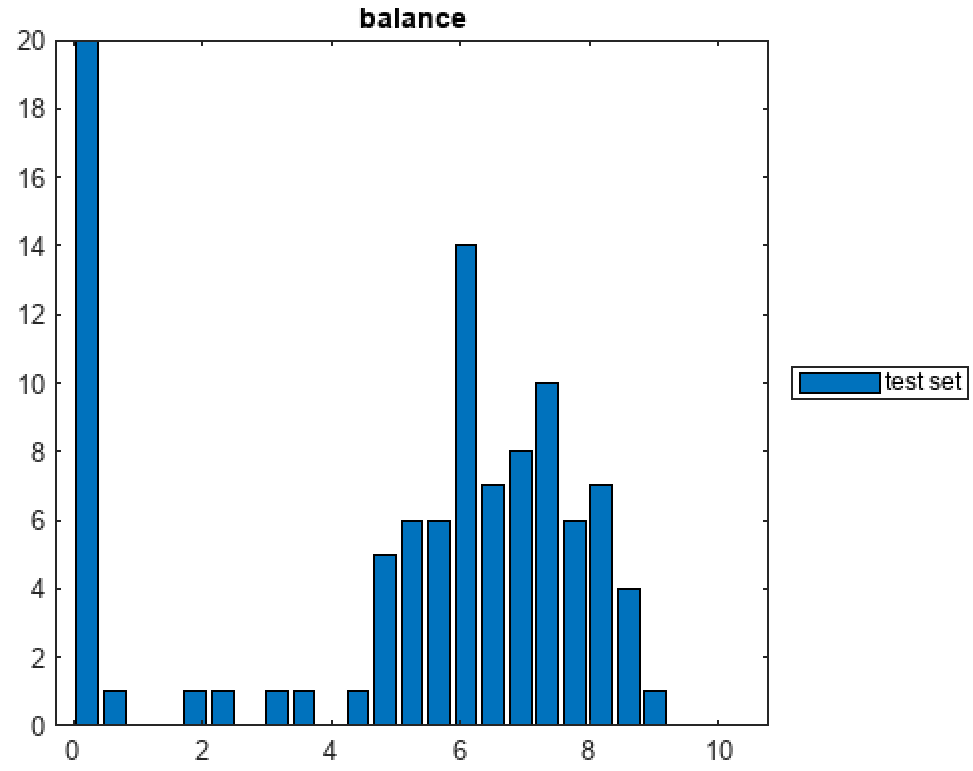

age
16
14
12
10
8
6
4
2
0
10
20
30
40
50
60
70
80
90
test set

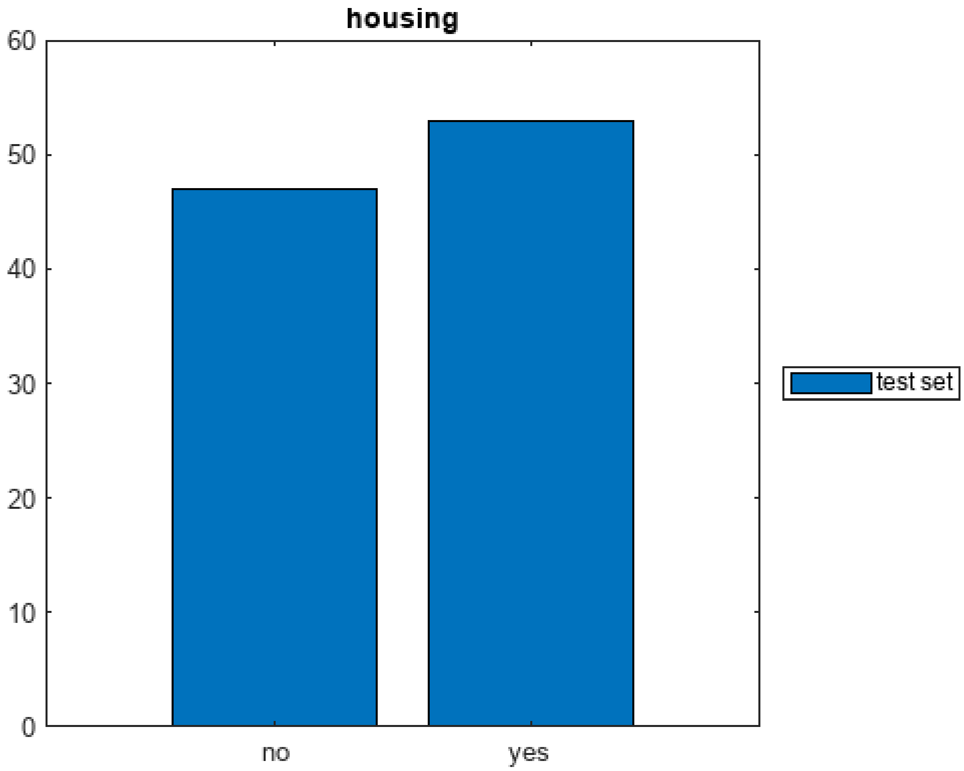

job
25
20
15
10
5
0
admin.
blue-collar
entrepreneur
housemaid
management
retired
self-employed
services
student
technician
unemployed
test set

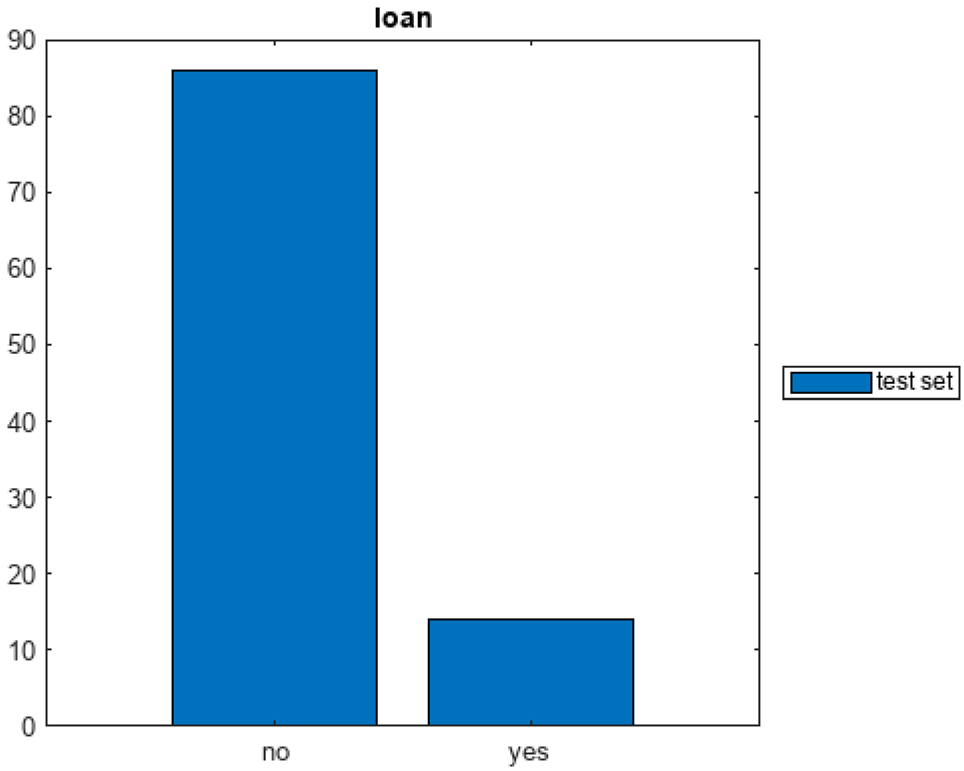

marital
70
60
50
40
30
20
10
0
divorced
married
single
test set

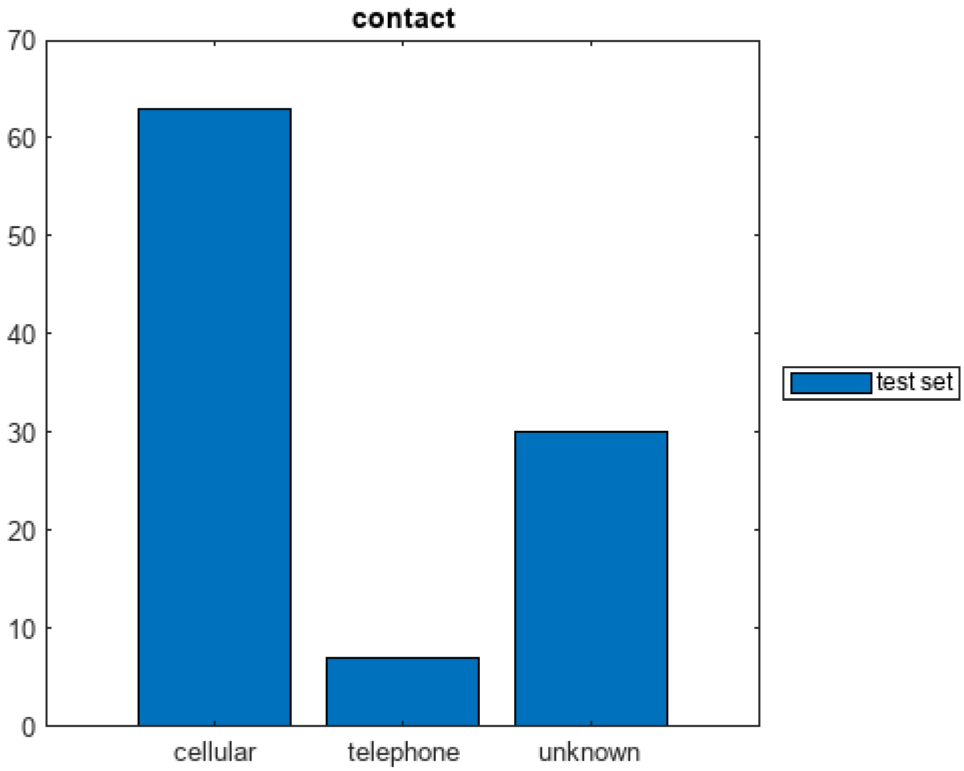

education
50
45
40
35
30
25
20
15
10
5
0
primary
secondary
tertiary
unknown
test set

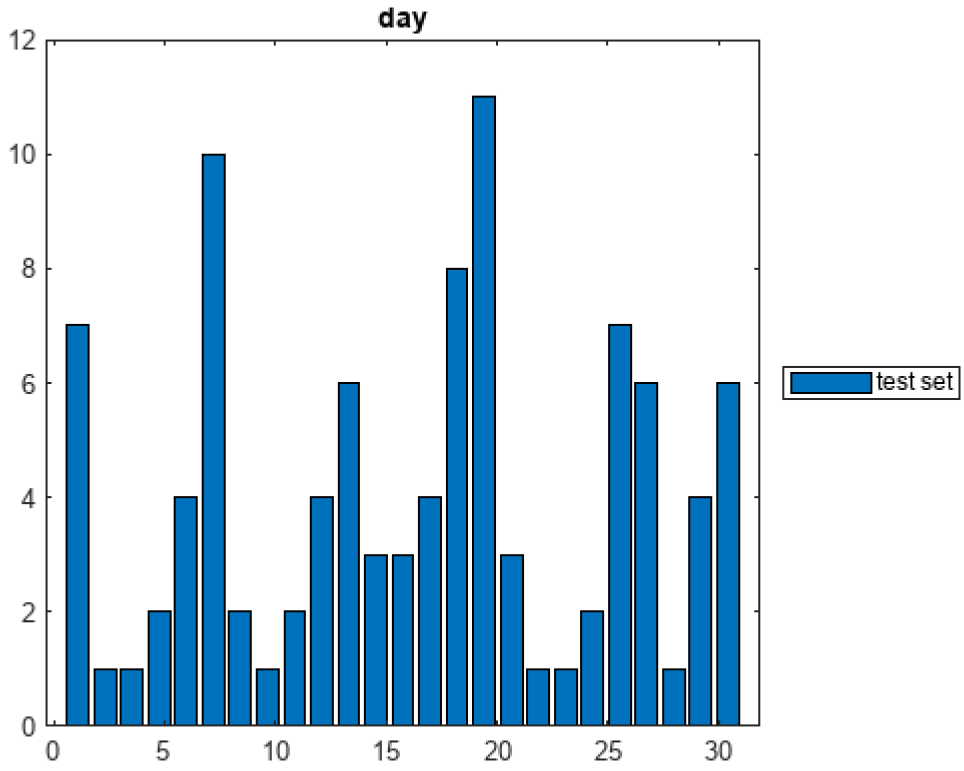

default
100
90
80
70
60
50
40
30
20
10
0
no
test set

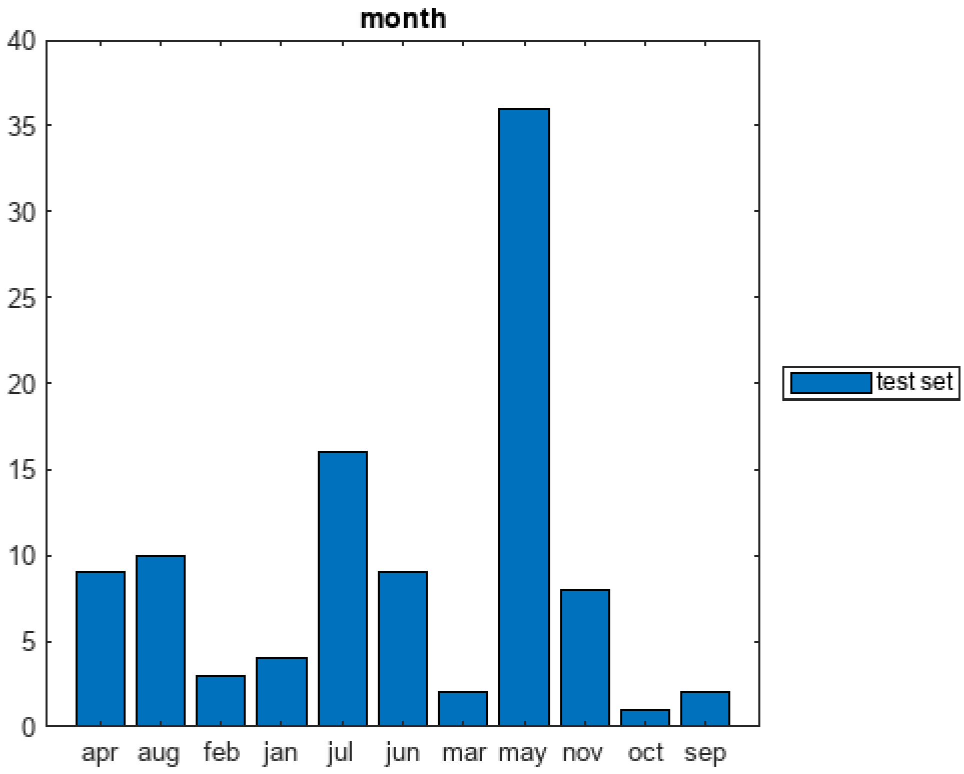

balance
20
18
16
14
12
10
8
6
4
2
0
0
2
4
6
8
10
test set

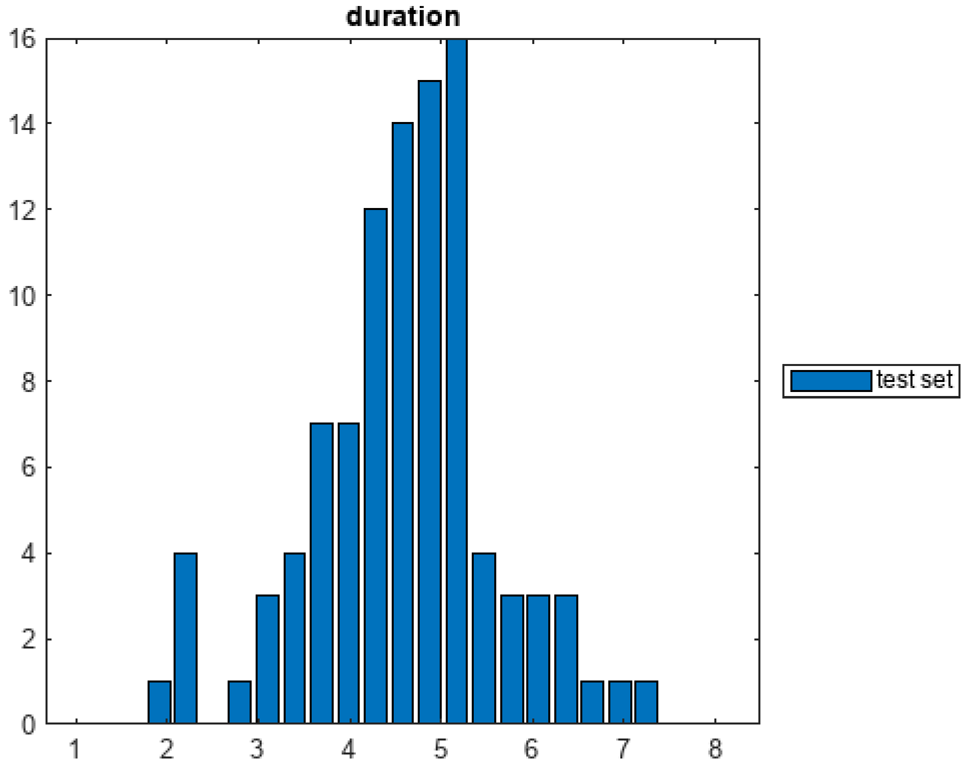

housing
60
50
40
30
20
10
0
no
yes
test set

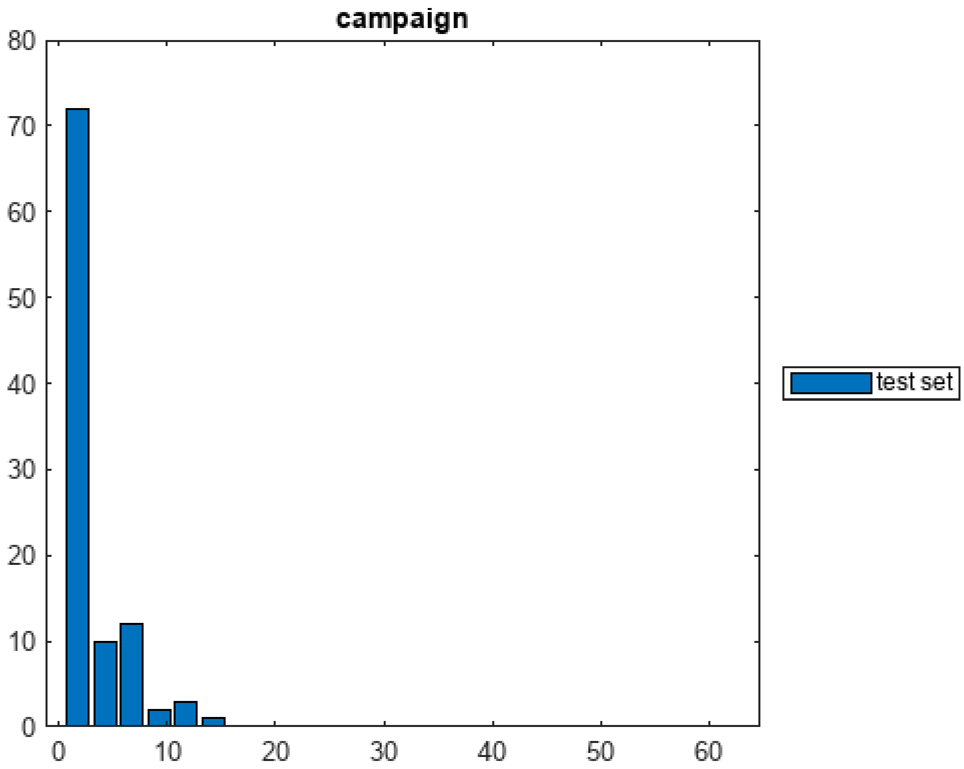

loan
90
80
70
60
50
40
30
20
10
0
no
yes
test set

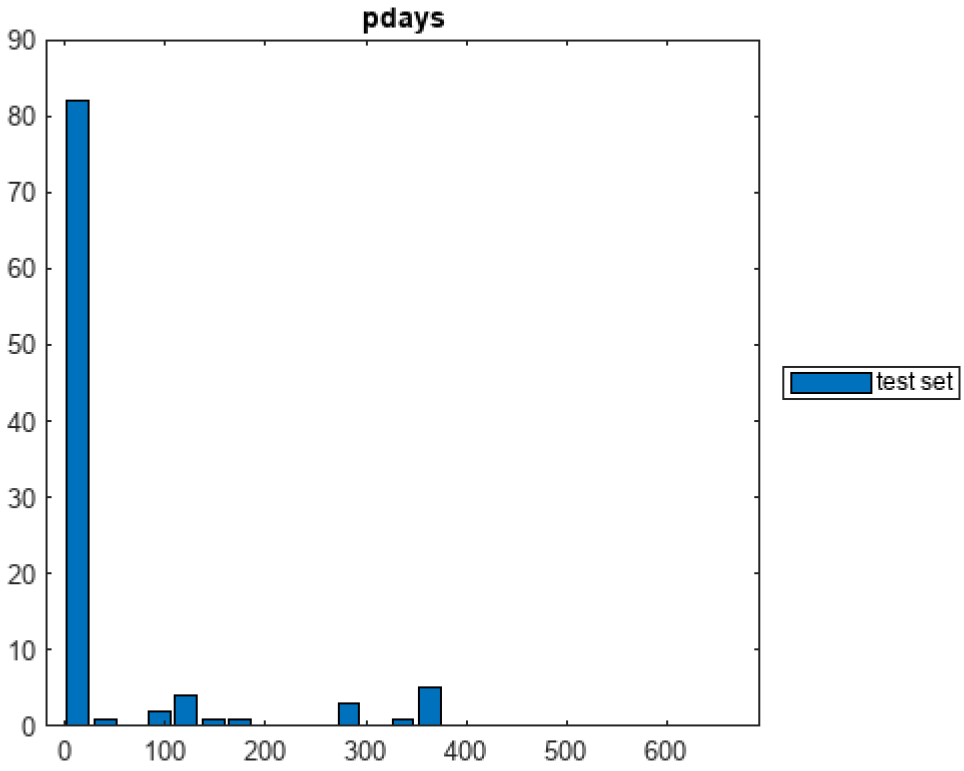

contact
70
60
50
40
30
20
10
0
cellular
telephone
unknown
test set

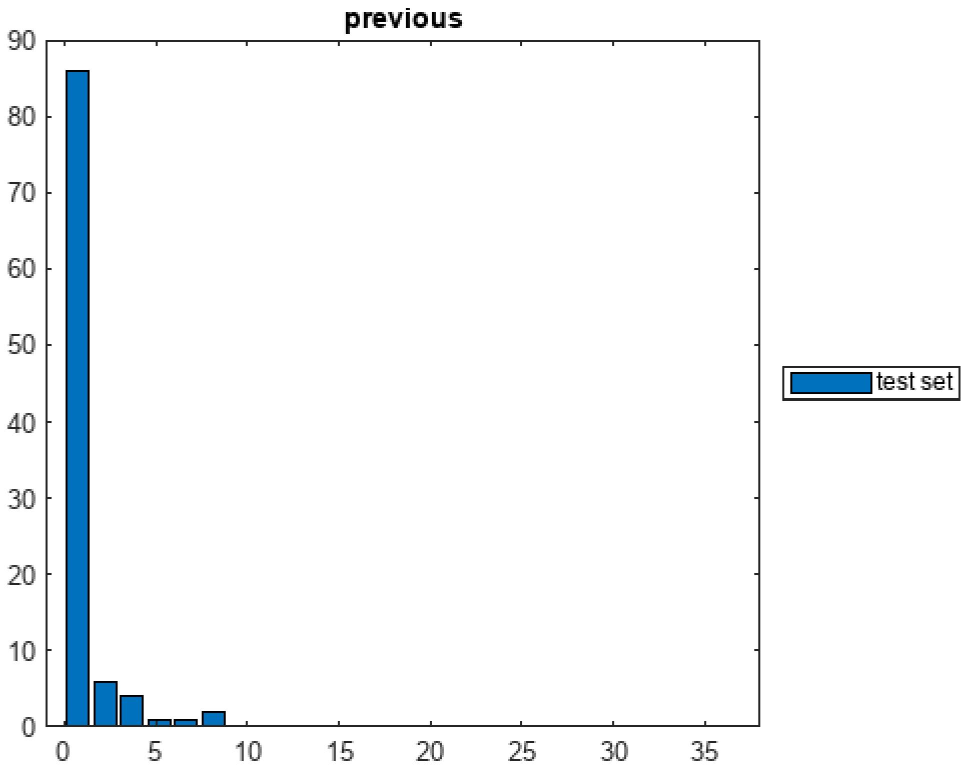

day
12
10
8
6
4
2
0
0
5
10
15
20
25
30
test set

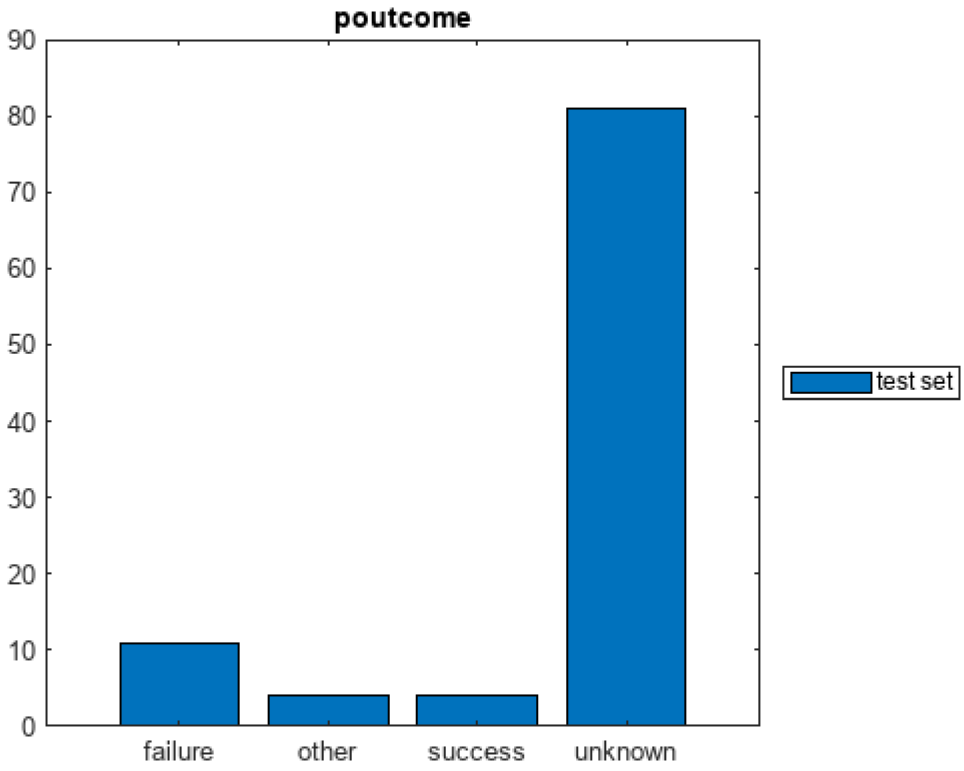

month
40
35
30
25
20
15
10
5
0
apr
aug
feb
jan
jul
jun
mar
may
nov
oct
sep
test set

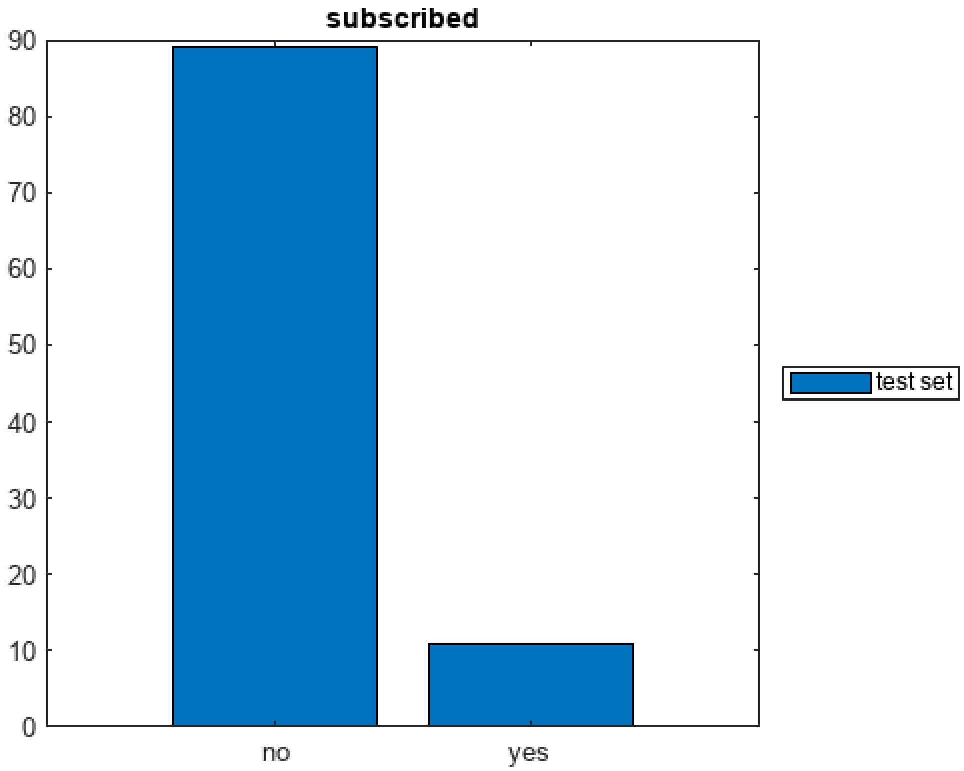

duration
16
14
12
10
8
6
4
2
0
1
2
3
4
5
6
7
8
test set

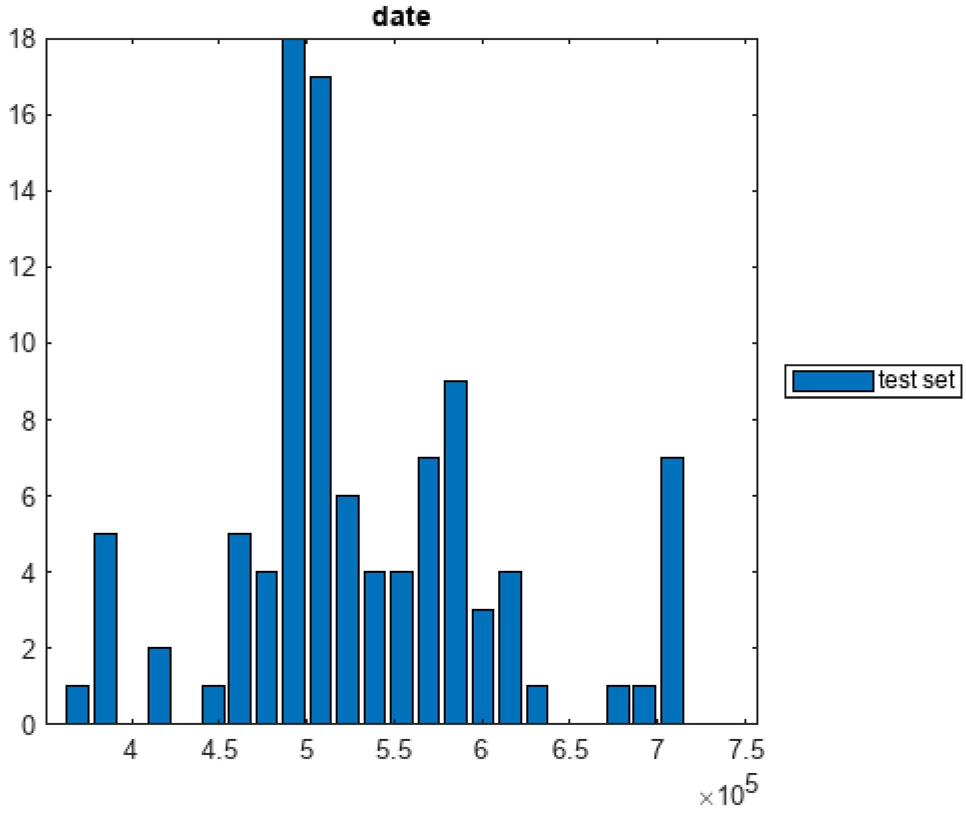

campaign
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
test set


pdays
90
80
70
60
50
40
30
20
10
0
0
100
200
300
400
500
600
test set


previous
90
80
70
60
50
40
30
20
10
0
0
5
10
15
20
25
30
35
test set

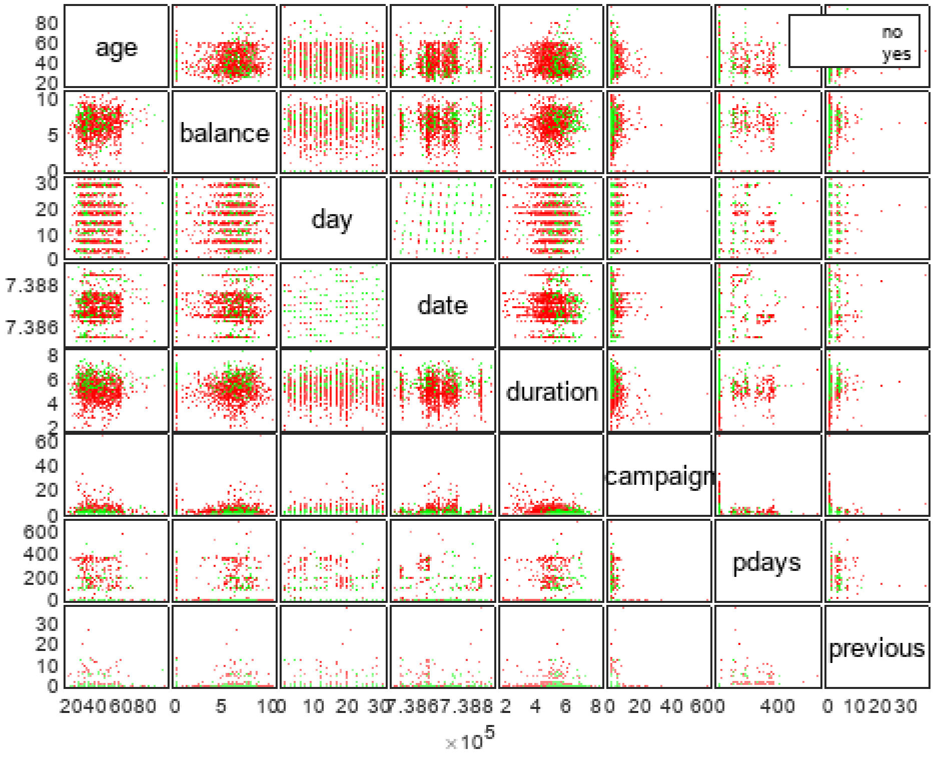

poutcome
90
80
70
60
50
40
30
20
10
0
failure
other
success
unknown
test set


subscribed
90
80
70
60
50
40
30
20
10
0
no
yes
test set


date
18
16
14
12
10
8
6
4
2
0
4
4.5
5
5.5
6
6.5
7
7.5
$\times 10^5$
test set

Gplot of non-categorical variables

```
X_ = [training_set.age training_set.balance training_set.day training_set.date, ...
      training_set.duration training_set.campaign training_set.pdays training_set.previous];

xnames = {'age', 'balance', 'day', 'date', 'duration', 'campaign', 'pdays', 'previous'};

figure
[h, ax] = gplotmatrix( X_,[],training_set.subscribed,['r','g'],[],[],[],'variable',xnames);
```



```
% saveas(gcf,strcat('figures/gplot_training.png') )
```

Clasiffication model: decission tree with all variables

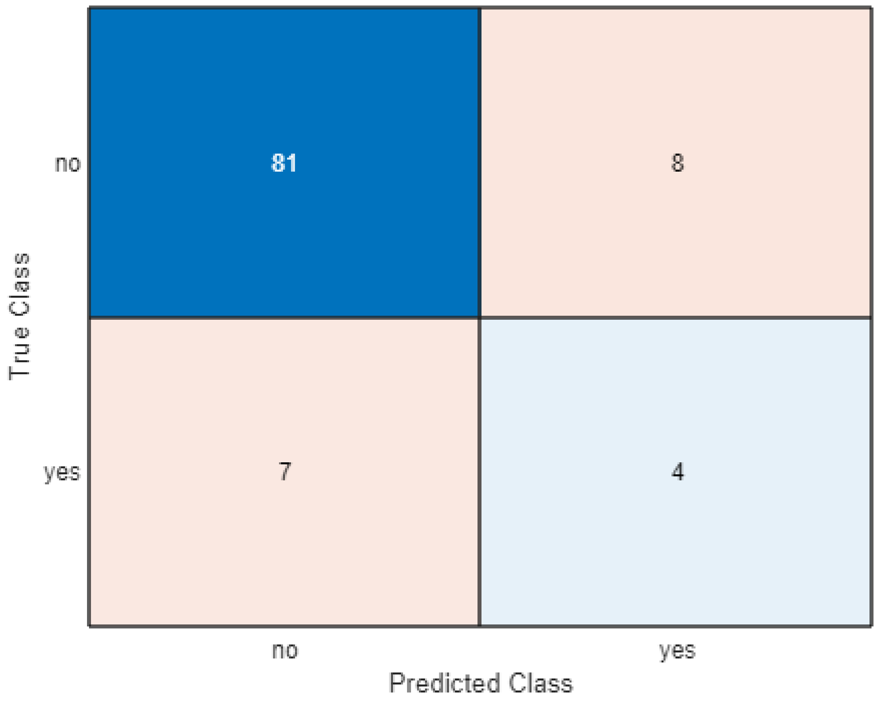
Train a decission tree with the provided dataset, capable of describing the subscription status of the client based on the other variables

```
tree = fitctree(training_set,'subscribed')
```

```
tree = 
  ClassificationTree
           PredictorNames: {'age'  'job'  'marital'  'education'  'default'  'balance'  'housing'  'loan'  'contact
             ResponseName: 'subscribed'
    CategoricalPredictors: [2 3 4 5 7 8 9 11 16]
               ClassNames: [no    yes]
```

```
          ScoreTransform: 'none'
         NumObservations: 2000

  Properties, Methods
```

```
[predictions_Tfull, scores_Tfull] = predict(tree,test_set);
confusionchart(test_set.subscribed,predictions_Tfull)
```



```
% saveas(gcf,strcat('figures/Confussion_Tfull.png') )
CrossVal_Tfull = kfoldLoss(crossval(tree))
```

```
CrossVal_Tfull = 0.1280
```

```
Accuracy_Tfull = accuracy(test_set.subscribed, predictions_Tfull, 'yes', 'no')
```

```
Accuracy_Tfull = 0.8500
```

```
Recall_Tfull = recall(test_set.subscribed, predictions_Tfull, 'yes', 'no')
```

```
Recall_Tfull = 0.3636
```

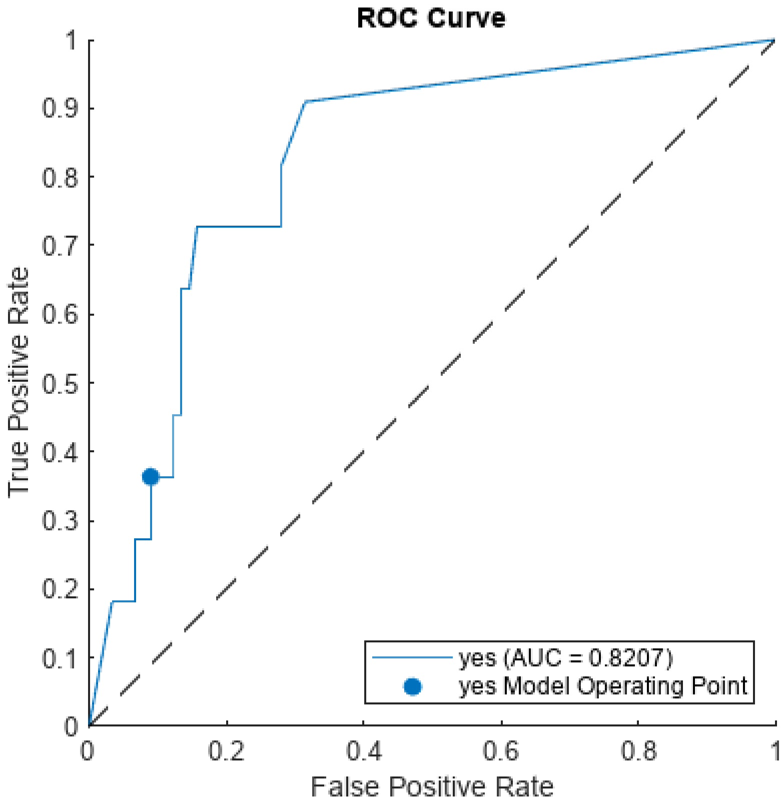
```
Precission_Tfull = precission(test_set.subscribed, predictions_Tfull, 'yes', 'no')
```

```
Precission_Tfull = 0.3333
```

```
rocObj = rocmetrics(test_set.subscribed, scores_Tfull, tree.ClassNames);
AUC_Tfull = rocObj.AUC(end)
```

```
AUC_Tfull = 0.8207
```

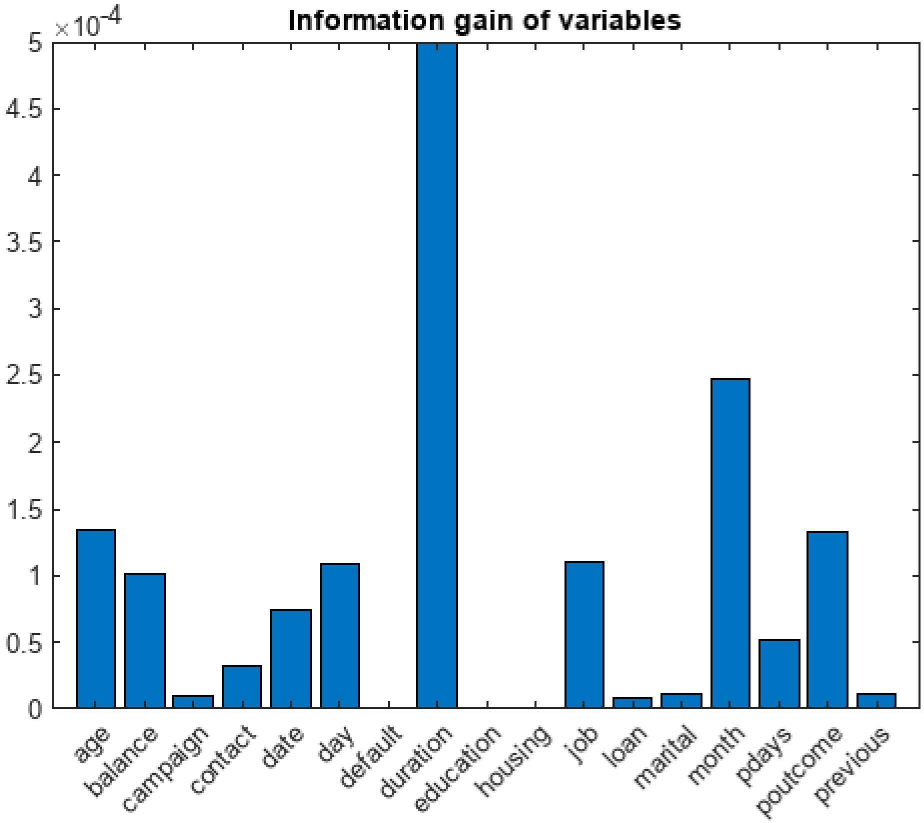
```
plot(rocObj,ClassNames='yes')
xlim([0,1])
ylim([0,1])
```



```
% saveas(gcf,strcat('figures/ROC_Tfull.png') )
```

Reduce number of variables

```
bar(categorical([test_set.Properties.VariableNames(1:end-2),test_set.Properties.VariableNames(e
    predictorImportance(tree))
title('Information gain of variables')
```

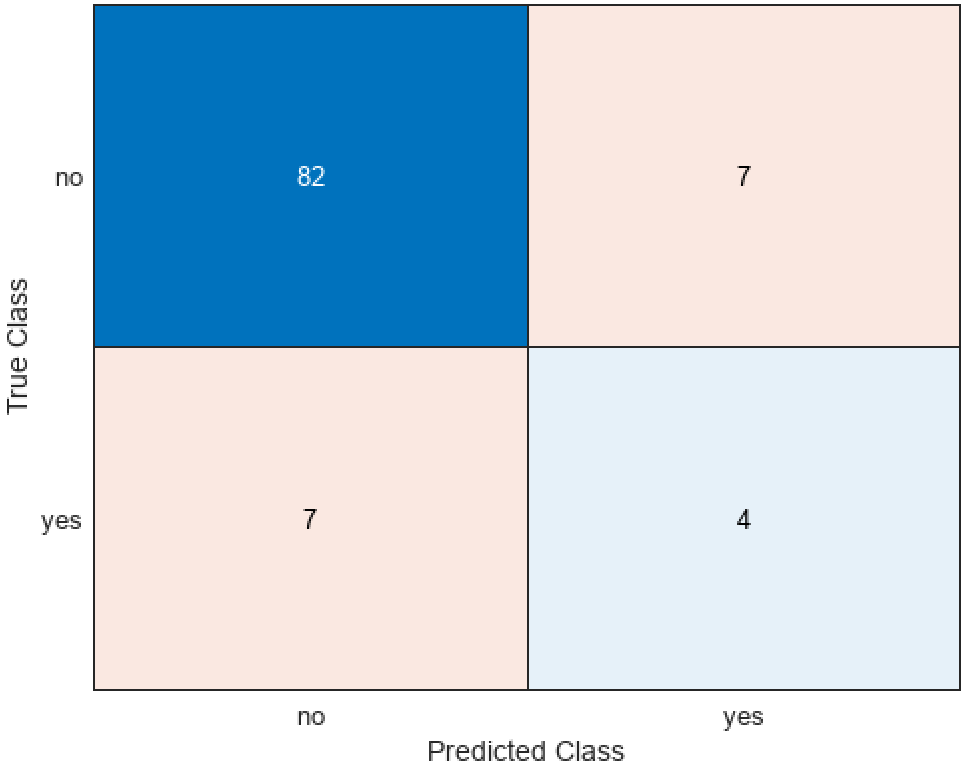


```
% saveas(gcf,strcat('figures/Vars_Tfull.png') )
```

```
tree_red = fitctree(removevars(training_set,{'default','education','housing','loan','marital',
```

```
tree_red = 
  ClassificationTree
           PredictorNames: {'age'  'job'  'balance'  'contact'  'day'  'month'  'duration'  'pdays'  'poutcome'}
             ResponseName: 'subscribed'
    CategoricalPredictors: [2 4 6 9]
               ClassNames: [no    yes]
           ScoreTransform: 'none'
          NumObservations: 2000


  Properties, Methods
```

```
[predictions_Tred, scores_Tred] = predict(tree_red,test_set);
confusionchart(test_set.subscribed,predictions_Tred)
```



```
% saveas(gcf,strcat('figures/Confussion_Tred.png') )
CrossVal_Tred = kfoldLoss(crossval(tree_red))
```

```
CrossVal_Tred = 0.1270
```

```

Accuracy_Tred = accuracy(test_set.subscribed, predictions_Tred, 'yes', 'no')
```

```
Accuracy_Tred = 0.8600
```

```
Recall_Tred = recall(test_set.subscribed, predictions_Tred, 'yes', 'no')
```

```
Recall_Tred = 0.3636
```

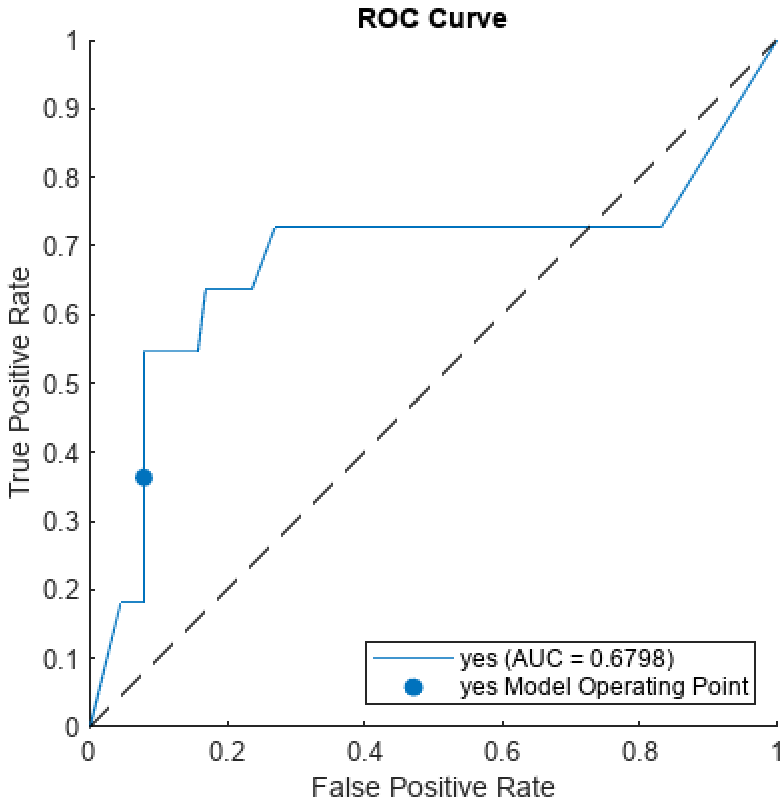
```
Precission_Tred = precission(test_set.subscribed, predictions_Tred, 'yes', 'no')
```

```
Precission_Tred = 0.3636
```

```
rocObj = rocmetrics(test_set.subscribed, scores_Tred, tree_red.ClassNames);
AUC_Tred = rocObj.AUC(end)
```

```
AUC_Tred = 0.6798
```

```
plot(rocObj,ClassNames='yes')
xlim([0,1])
ylim([0,1])
```



```
% saveas(gcf,strcat('figures/ROC_Tred.png') )
```

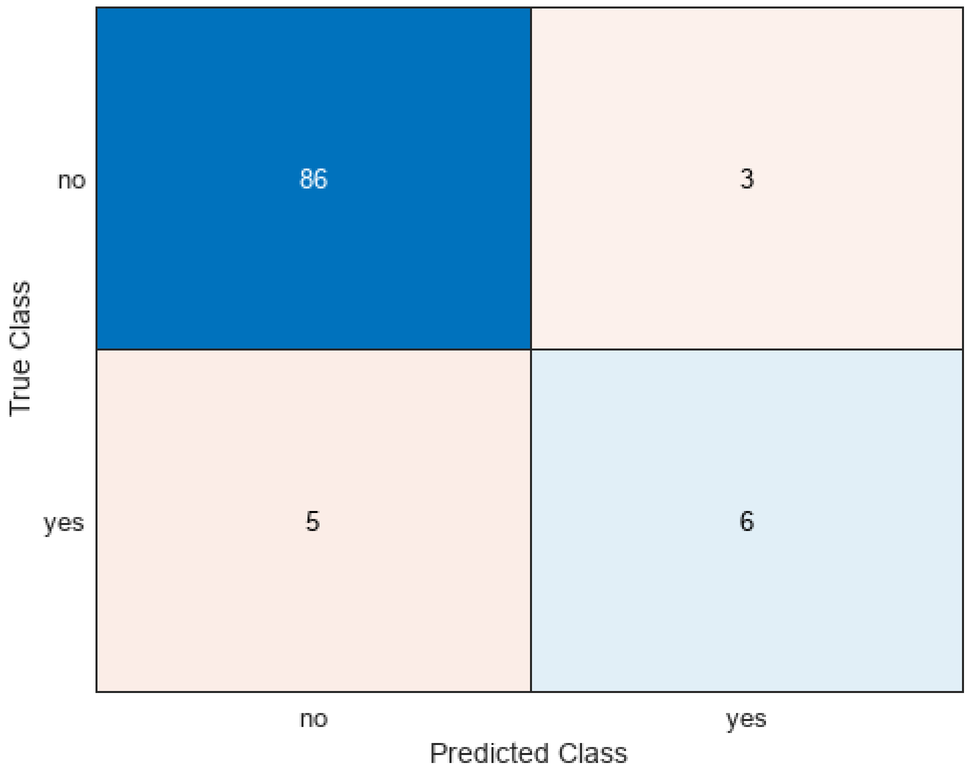
Clasiffication model: Naive Bayes

Train a decission tree with the provided dataset, capable of describing the subscription status of the client based on the other variables

```
NaiveBayes = fitcnb(training_set,'subscribed')
```

```
NaiveBayes = 
  ClassificationNaiveBayes
           PredictorNames: {'age'  'job'  'marital'  'education'  'default'  'balance'  'housing'  'loan'  'contact
             ResponseName: 'subscribed'
    CategoricalPredictors: [2 3 4 5 7 8 9 11 16]
               ClassNames: [no    yes]
           ScoreTransform: 'none'
          NumObservations: 2000
        DistributionNames: {'normal'  'mvmn'  'mvmn'  'mvmn'  'mvmn'  'normal'  'mvmn'  'mvmn'  'mvmn'  'normal'
   DistributionParameters: {2×17 cell}
        CategoricalLevels: {[]  [12×1 double]  [3×1 double]  [4×1 double]  [2×1 double]  []  [2×1 double]  [2×1 dou


  Properties, Methods
```

```
[predictions_NB, scores_NB] = predict(NaiveBayes,test_set);
confusionchart(test_set.subscribed,predictions_NB)
```



```
% saveas(gcf,strcat('figures/Confussion_NB.png') )
CrossVal_NB = kfoldLoss(crossval(NaiveBayes))
```

```
CrossVal_NB = 0.1250
```

```

Accuracy_NB = accuracy(test_set.subscribed, predictions_NB, 'yes', 'no')
```

```
Accuracy_NB = 0.9200
```

```
Recall_NB = recall(test_set.subscribed, predictions_NB, 'yes', 'no')
```

```
Recall_NB = 0.5455
```

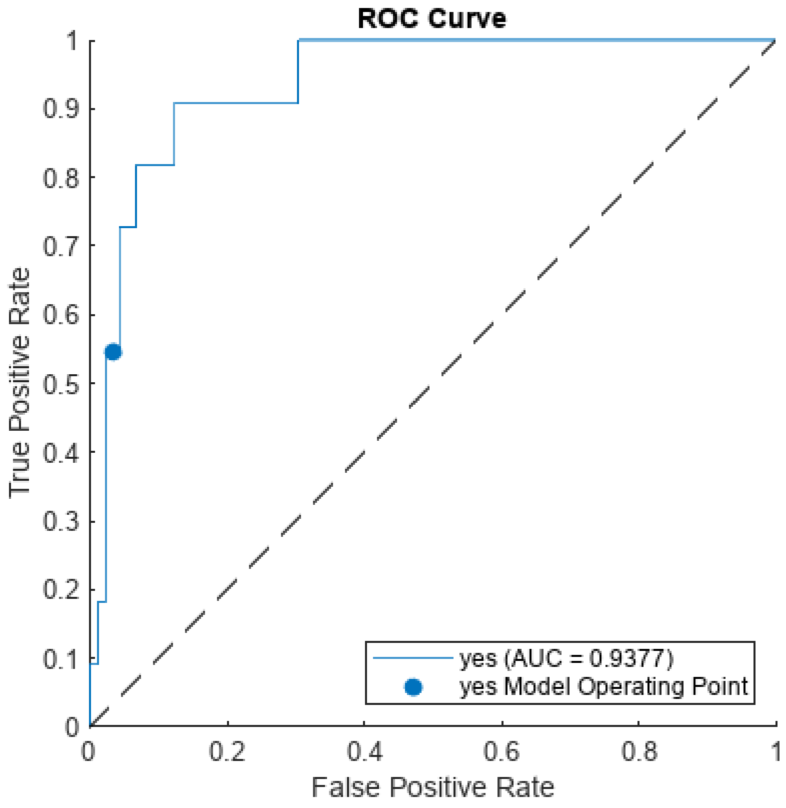
```
Precission_NB = precission(test_set.subscribed, predictions_NB, 'yes', 'no')
```

```
Precission_NB = 0.6667
```

```
rocObj = rocmetrics(test_set.subscribed, scores_NB, NaiveBayes.ClassNames);
AUC_NB = rocObj.AUC(end)
```

```
AUC_NB = 0.9377
```

```
plot(rocObj,ClassNames='yes')
xlim([0,1])
ylim([0,1])
```



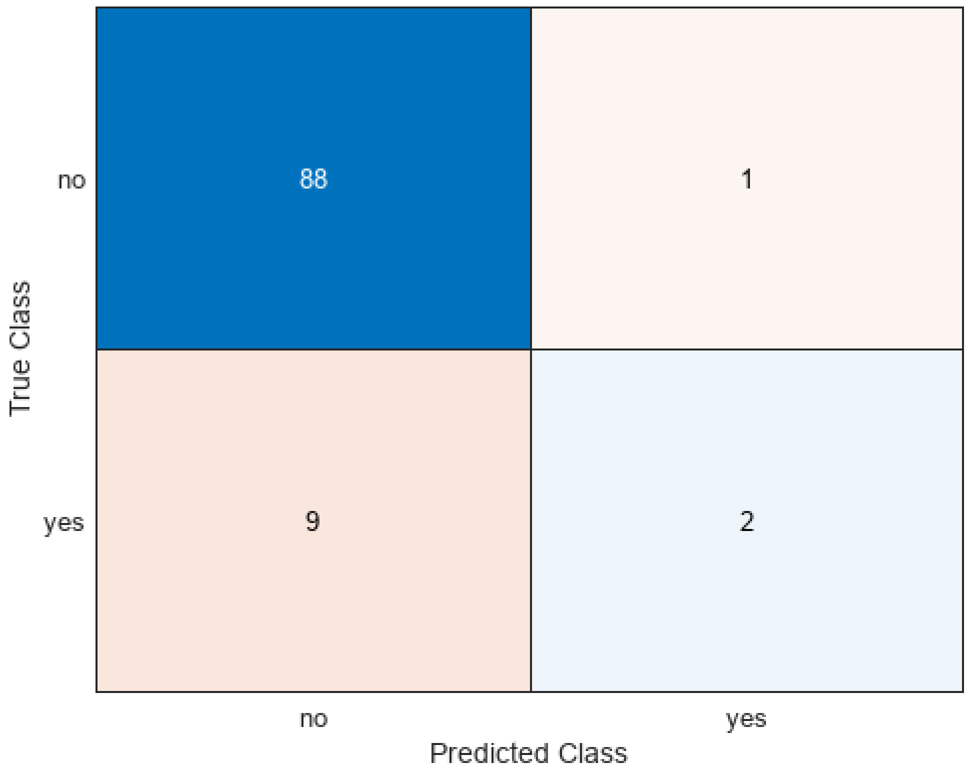
```
% saveas(gcf,strcat('figures/ROC_NB.png') )
```

Include prior probabilities

```
prob_subscribed = sum(training_set.subscribed == 'yes')/numel(training_set);
% classNames = ['yes', 'no'];
prior = [1-prob_subscribed prob_subscribed];

NB_prior = fitcnb(training_set,'subscribed','Prior',prior)
```

```
NB_prior = 
  ClassificationNaiveBayes
            PredictorNames: {'age'  'job'  'marital'  'education'  'default'  'balance'  'housing'  'loan'  'contac
              ResponseName: 'subscribed'
     CategoricalPredictors: [2 3 4 5 7 8 9 11 16]
                ClassNames: [no     yes]
            ScoreTransform: 'none'
           NumObservations: 2000
         DistributionNames: {'normal'  'mvmn'  'mvmn'  'mvmn'  'mvmn'  'normal'  'mvmn'  'mvmn'  'mvmn'  'normal'
    DistributionParameters: {2×17 cell}
         CategoricalLevels: {[]  [12×1 double]  [3×1 double]  [4×1 double]  [2×1 double]  []  [2×1 double]  [2×1 dou


  Properties, Methods
```

```
% NB_prior = fitcnb(training_set,'subscribed','ClassNames',classNames,'Prior',prior)

[predictions_NBprior, scores_NBprior] = predict(NB_prior,test_set);
confusionchart(test_set.subscribed,predictions_NBprior)
```



```
% saveas(gcf,strcat('figures/Confussion_NBprior.png') )
CrossVal_NBprior = kfoldLoss(crossval(NB_prior))
```

```
CrossVal_NBprior = 0.0193
```

```

Accuracy_NBprior = accuracy(test_set.subscribed, predictions_NBprior, 'yes', 'no')
```

```
Accuracy_NBprior = 0.9000
```

```
Recall_NBprior = recall(test_set.subscribed, predictions_NBprior, 'yes', 'no')
```

```
Recall_NBprior = 0.1818
```

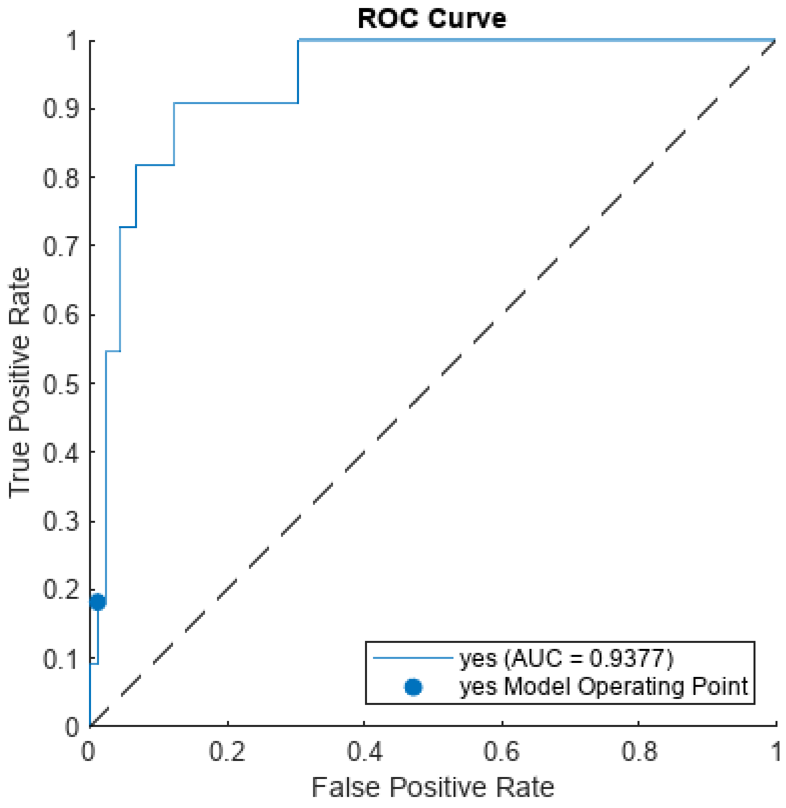
```
Precission_NBprior = precission(test_set.subscribed, predictions_NBprior, 'yes', 'no')
```

```
Precission_NBprior = 0.6667
```

```
rocObj = rocmetrics(test_set.subscribed, scores_NBprior, NB_prior.ClassNames);
AUC_NBprior = rocObj.AUC(end)
```

```
AUC_NBprior = 0.9377
```

```
plot(rocObj,ClassNames='yes')
xlim([0,1])
ylim([0,1])
```



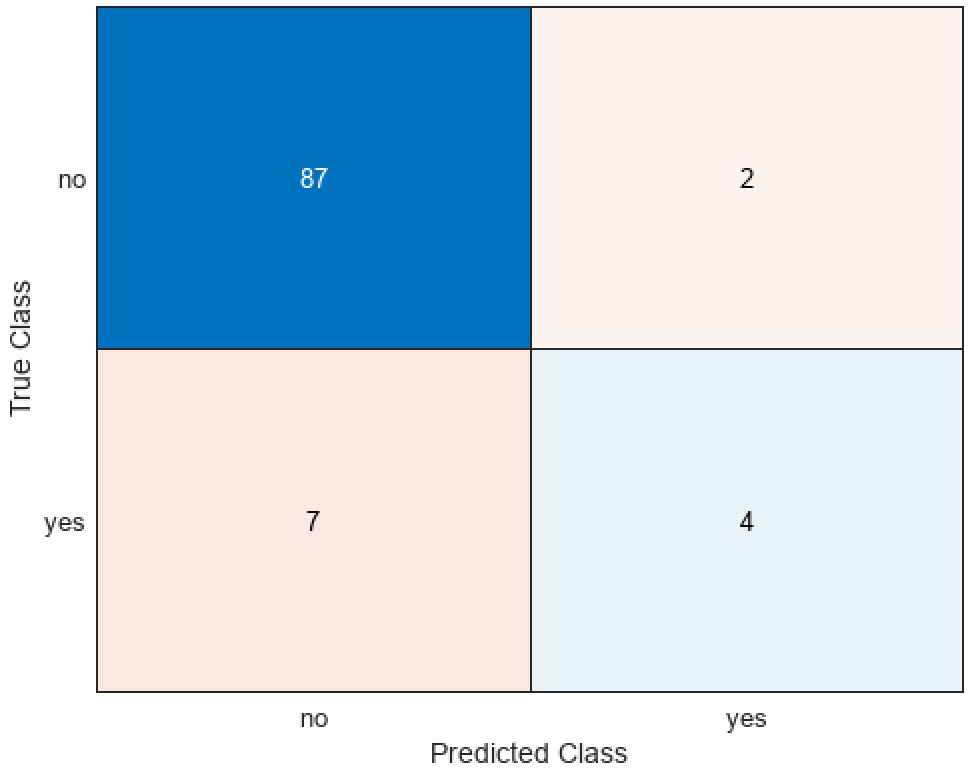
```
% saveas(gcf,strcat('figures/ROC_NBprior.png') )
```

Reduce number of variables

```
NB_red = fitcnb(removevars(training_set,{'default','education','housing','loan','marital','prev
```

```
NB_red = 
  ClassificationNaiveBayes
           PredictorNames: {'age'  'job'  'balance'  'contact'  'day'  'month'  'duration'  'pdays'  'poutcome'}
             ResponseName: 'subscribed'
    CategoricalPredictors: [2 4 6 9]
               ClassNames: [no    yes]
           ScoreTransform: 'none'
          NumObservations: 2000
        DistributionNames: {'normal'  'mvmn'  'normal'  'mvmn'  'normal'  'mvmn'  'normal'  'normal'  'mvmn'}
   DistributionParameters: {2×9 cell}
        CategoricalLevels: {[]  [12×1 double]  []  [3×1 double]  []  [12×1 double]  []  []  [4×1 double]}


  Properties, Methods
```

```
[predictions_NBred, scores_NBred] = predict(NB_red,test_set);
confusionchart(test_set.subscribed,predictions_NBred)
```



```
% saveas(gcf,strcat('figures/Confussion_NBred.png') )
CrossVal_NBred = kfoldLoss(crossval(NB_red))
```

```
CrossVal_NBred = 0.1075
```

```

Accuracy_NBred = accuracy(test_set.subscribed, predictions_NBred, 'yes', 'no')
```

```
Accuracy_NBred = 0.9100
```

```
Recall_NBred = recall(test_set.subscribed, predictions_NBred, 'yes', 'no')
```

```
Recall_NBred = 0.3636
```

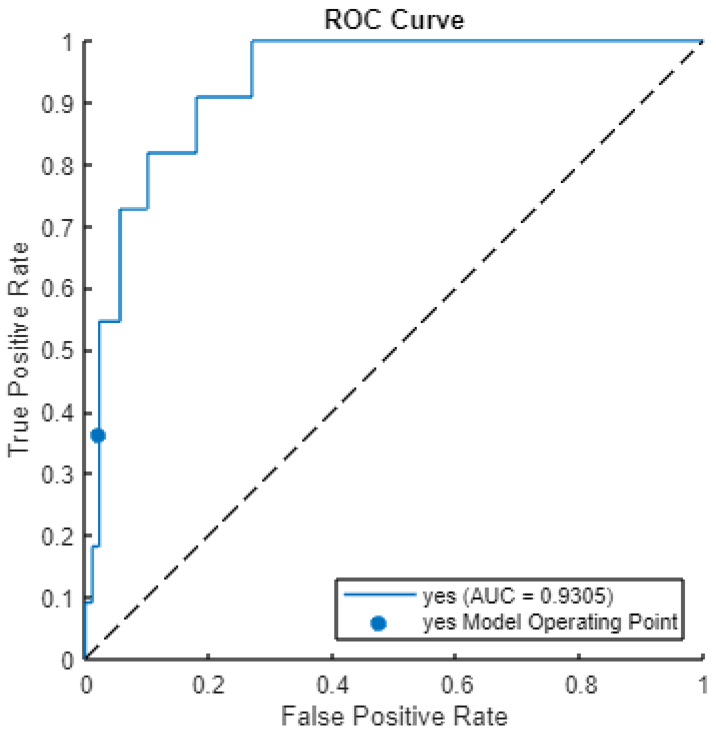
```
Precission_NBred = precission(test_set.subscribed, predictions_NBred, 'yes', 'no')
```

```
Precission_NBred = 0.6667
```

```
rocObj = rocmetrics(test_set.subscribed, scores_NBred, NB_red.ClassNames);
AUC_NBred = rocObj.AUC(end)
```

```
AUC_NBred = 0.9305
```

```
plot(rocObj,ClassNames='yes')
xlim([0,1])
ylim([0,1])
```



```
% saveas(gcf,strcat('figures/ROC_NBred.png') )
```

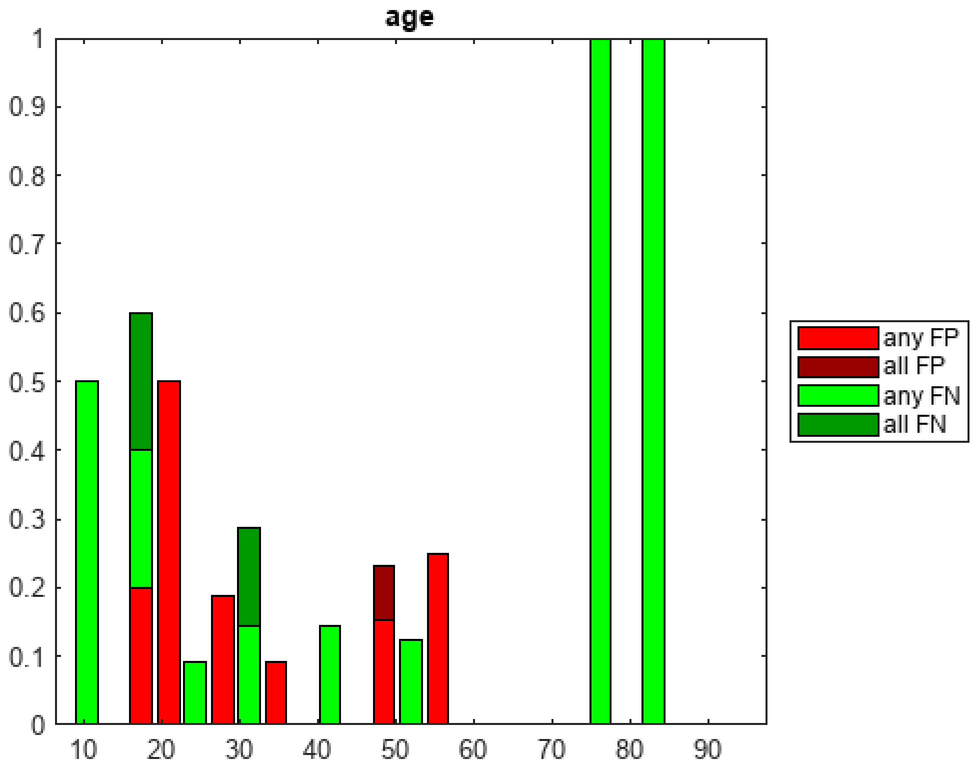
Analysis of False Positives and False Negatives

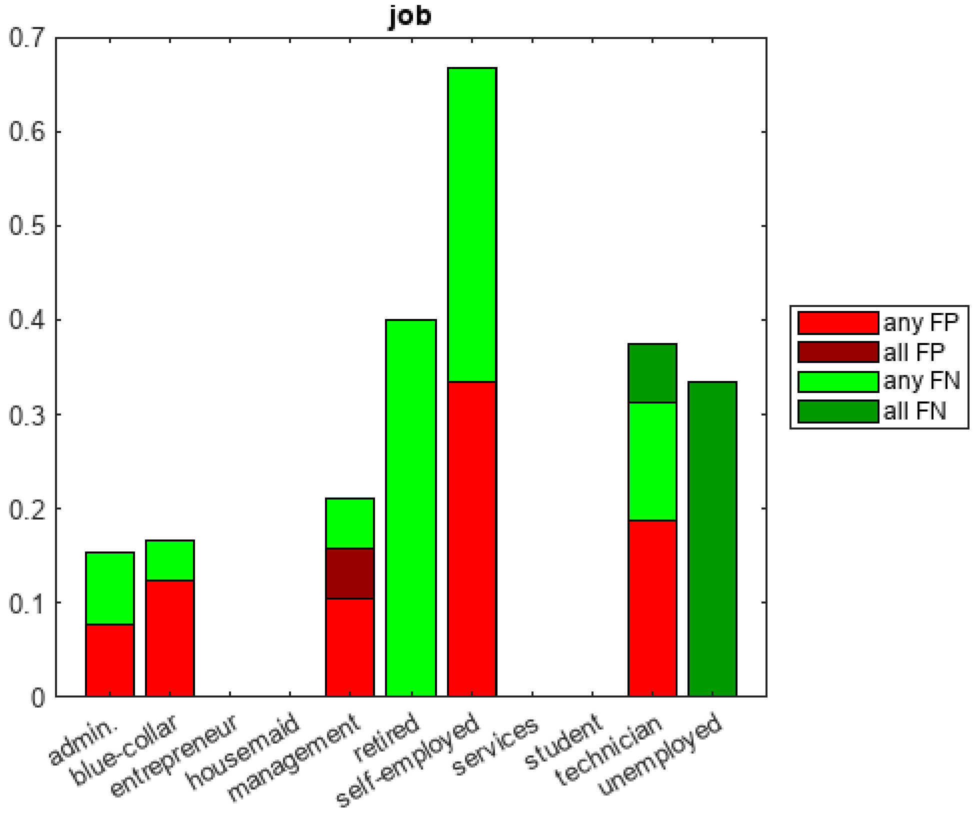
```
% Indexes of false positives for different methods
i_FP = [test_set.subscribed == 'no' & predictions_Tfull == 'yes', ...
        test_set.subscribed == 'no' & predictions_Tred == 'yes', ...
        test_set.subscribed == 'no' & predictions_NB == 'yes', ...
        test_set.subscribed == 'no' & predictions_NBprior == 'yes', ...
        test_set.subscribed == 'no' & predictions_NBred == 'yes'];

i_FN = [test_set.subscribed == 'yes' & predictions_Tfull == 'no', ...
        test_set.subscribed == 'yes' & predictions_Tred == 'no', ...
        test_set.subscribed == 'yes' & predictions_NB == 'no', ...
        test_set.subscribed == 'yes' & predictions_NBprior == 'no', ...
        test_set.subscribed == 'yes' & predictions_NBred == 'no'];

test_set.FP = sum(i_FP, 2);
test_set.FN = sum(i_FN, 2);

FP_set_any = test_set(test_set.FP>0 & test_set.FP<5,:);
FP_set_all = test_set(test_set.FP==5,:);
FN_set_any = test_set(test_set.FN>0 & test_set.FN<5,:);
FN_set_all = test_set(test_set.FN==5,:);
```

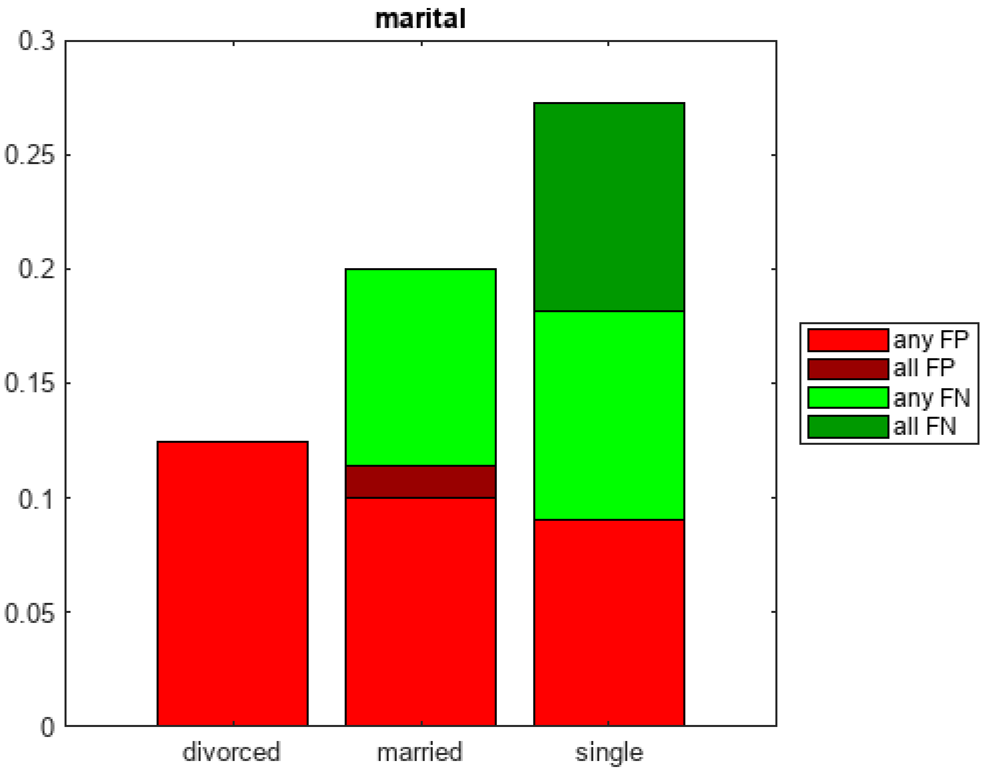
Make some graphs

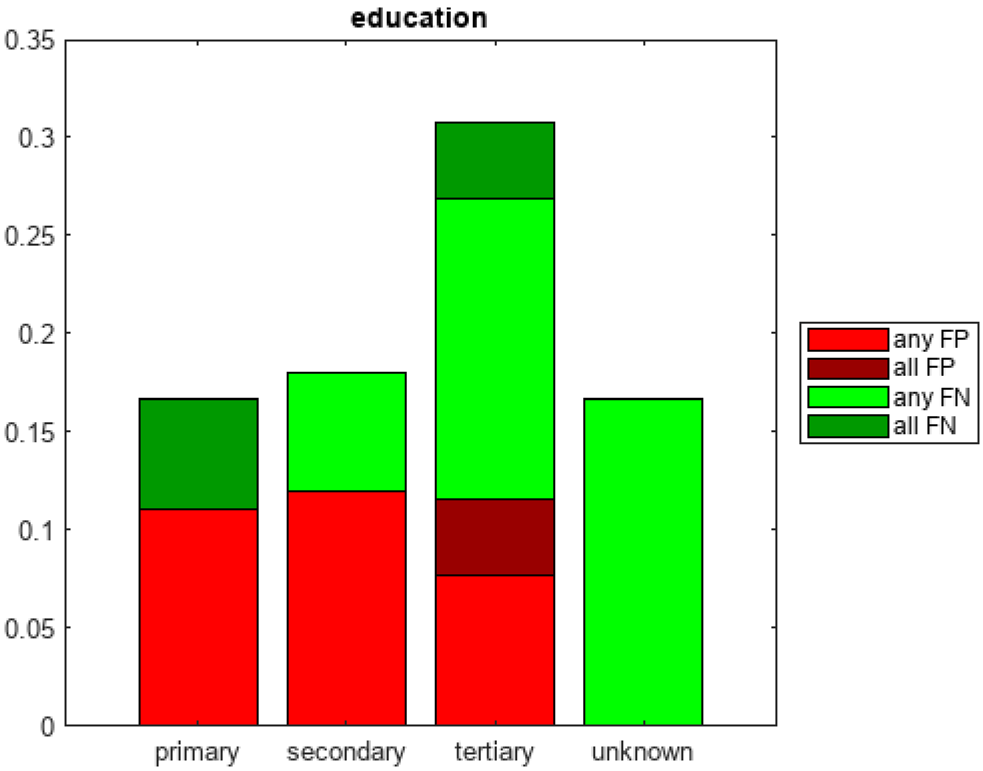
```
nbins = 25;

for col = 1: width(training_set)
    figure

    if iscategorical(table2array(test_set(:,col)))
        Y(1,:) = countcats( table2array(FP_set_any(:,col)) ) ./ ...
                 countcats( table2array(test_set(:,col)) );
        Y(2,:) = countcats( table2array(FP_set_all(:,col)) )' ./ ...
                 countcats( table2array(test_set(:,col)) );
        Y(3,:) = countcats( table2array(FN_set_any(:,col)) ) ./ ...
                 countcats( table2array(test_set(:,col)) );
        Y(4,:) = countcats( table2array(FN_set_all(:,col)) ) ./ ...
                 countcats( table2array(test_set(:,col)) );

        ba = bar(categorical(categories(table2array(test_set(:,col)))), ...
                 Y', 'stacked', 'FaceColor','flat');
        ba(1).CData = [1.0 0   0];
        ba(2).CData = [0.6 0   0];
        ba(3).CData = [0   1.0 0];
        ba(4).CData = [0   0.6 0];
        clear Y
    else
        hist_edges = linspace(min(table2array(training_set(:,col))), ...
                              max(table2array(training_set(:,col))), nbins+1);
        plot_edges = linspace(hist_edges(2)/2, (hist_edges(end-1)+hist_edges(end))/2, nbins);

        X(1,:) = histcounts( table2array(FP_set_any(:,col)), hist_edges) ./ ...
                 histcounts( table2array(test_set(:,col)), hist_edges);
        X(2,:) = histcounts( table2array(FP_set_all(:,col)), hist_edges) ./ ...
                 histcounts( table2array(test_set(:,col)), hist_edges);
        X(3,:) = histcounts( table2array(FN_set_any(:,col)), hist_edges) ./ ...
                 histcounts( table2array(test_set(:,col)), hist_edges);
        X(4,:) = histcounts( table2array(FN_set_all(:,col)), hist_edges) ./ ...
                 histcounts( table2array(test_set(:,col)), hist_edges);

        ba = bar(plot_edges, X', 'stacked', 'FaceColor','flat');
        ba(1).CData = [1.0 0   0];
        ba(2).CData = [0.6 0   0];
        ba(3).CData = [0   1.0 0];
        ba(4).CData = [0   0.6 0];
    end

    title(training_set.Properties.VariableNames{col})
    if col == 5
        title(' default ')
    end
    legend('any FP','all FP','any FN','all FN','Location','eastoutside')
```

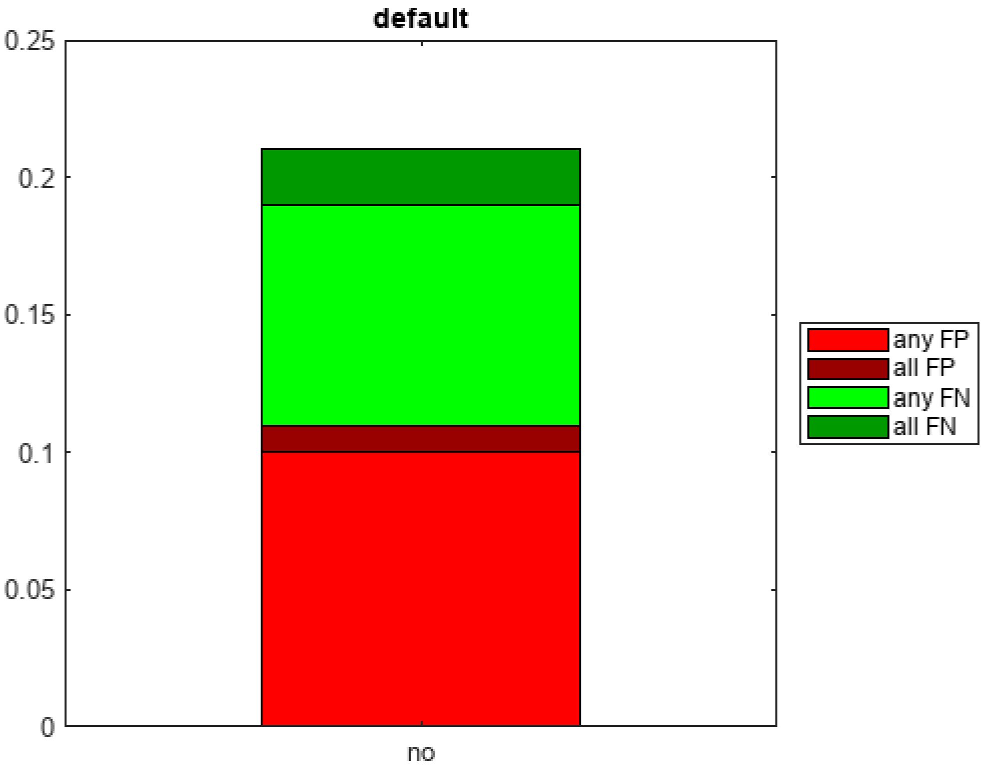
```
%     saveas(gcf,strcat('figures/Hist_FPFN_', test_set.Properties.VariableNames{col}, '.png')
end
```

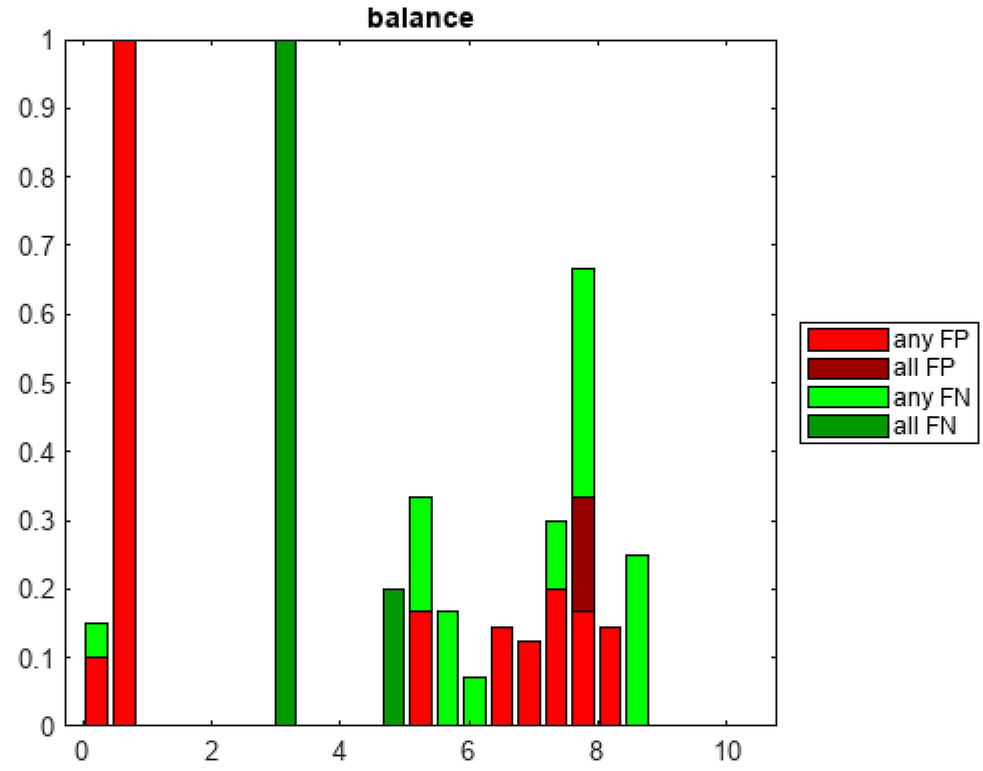


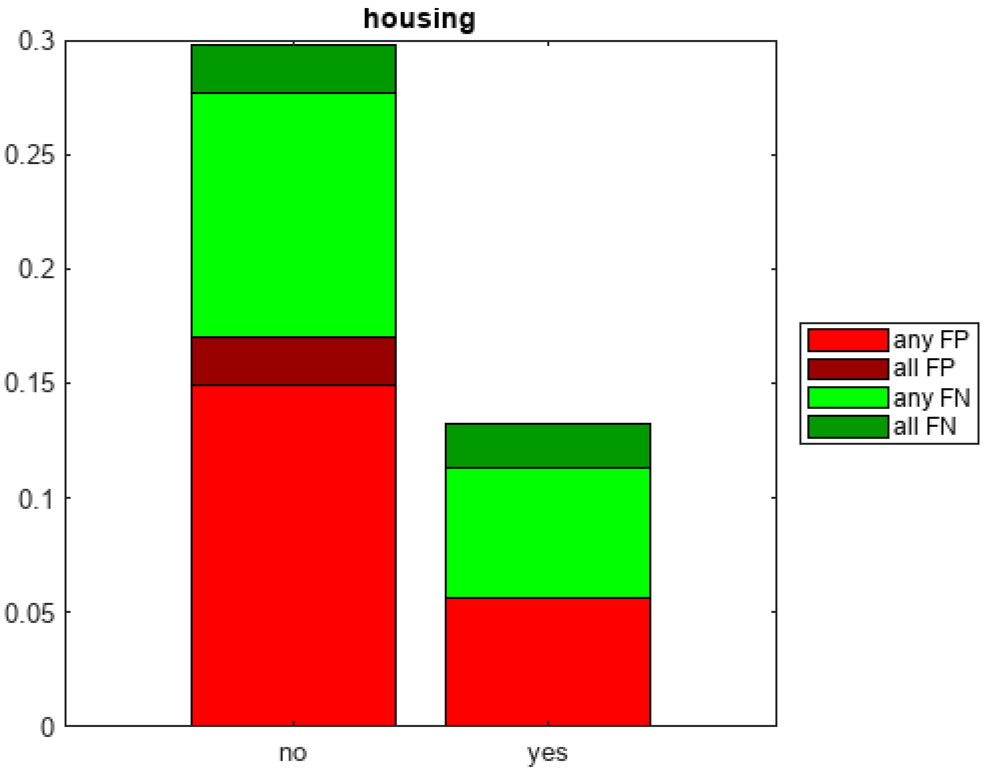


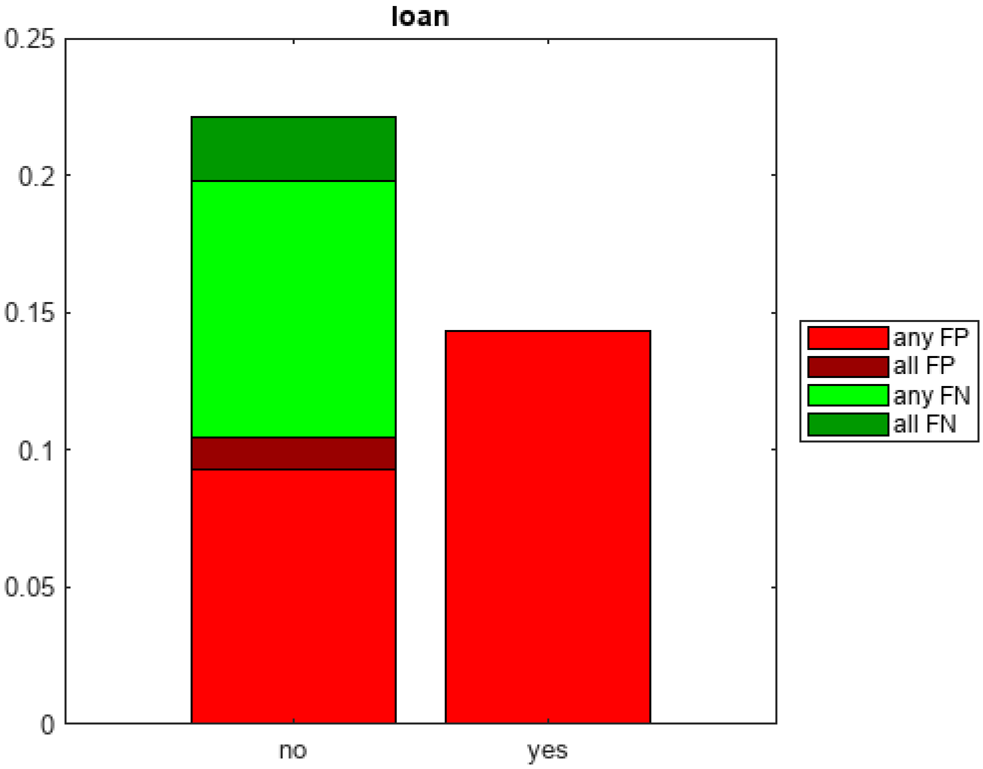

marital
0.3
0.25
0.2
0.15
0.1
0.05
0
divorced
married
single
any FP
all FP
any FN
all FN

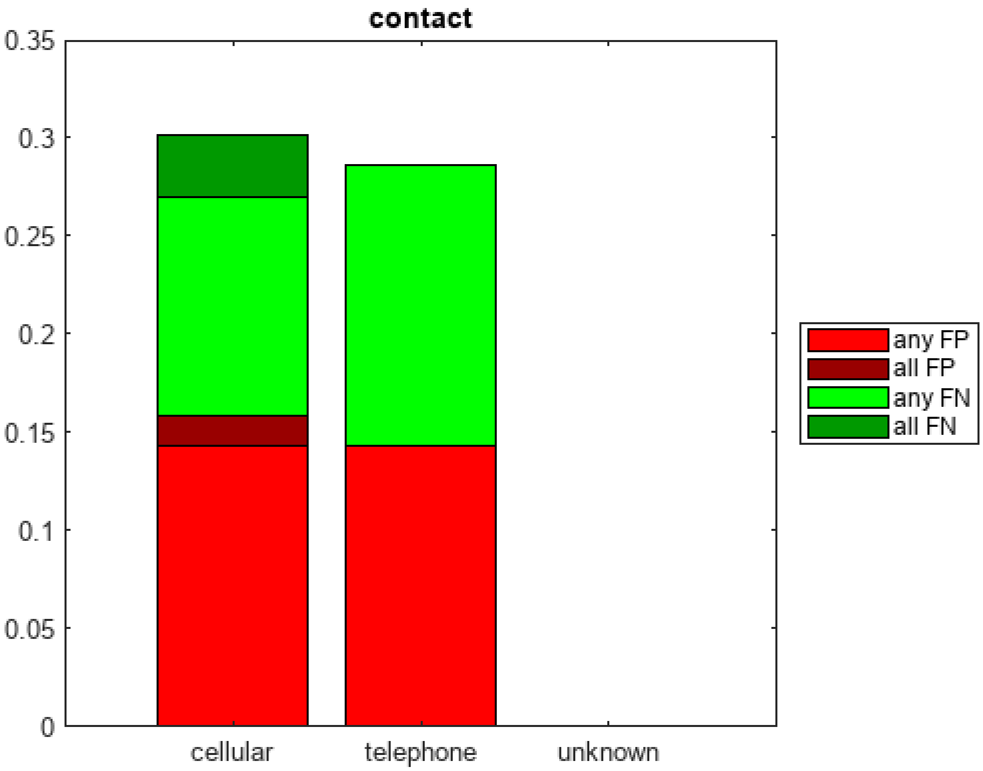

education
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
primary
secondary
tertiary
unknown
any FP
all FP
any FN
all FN

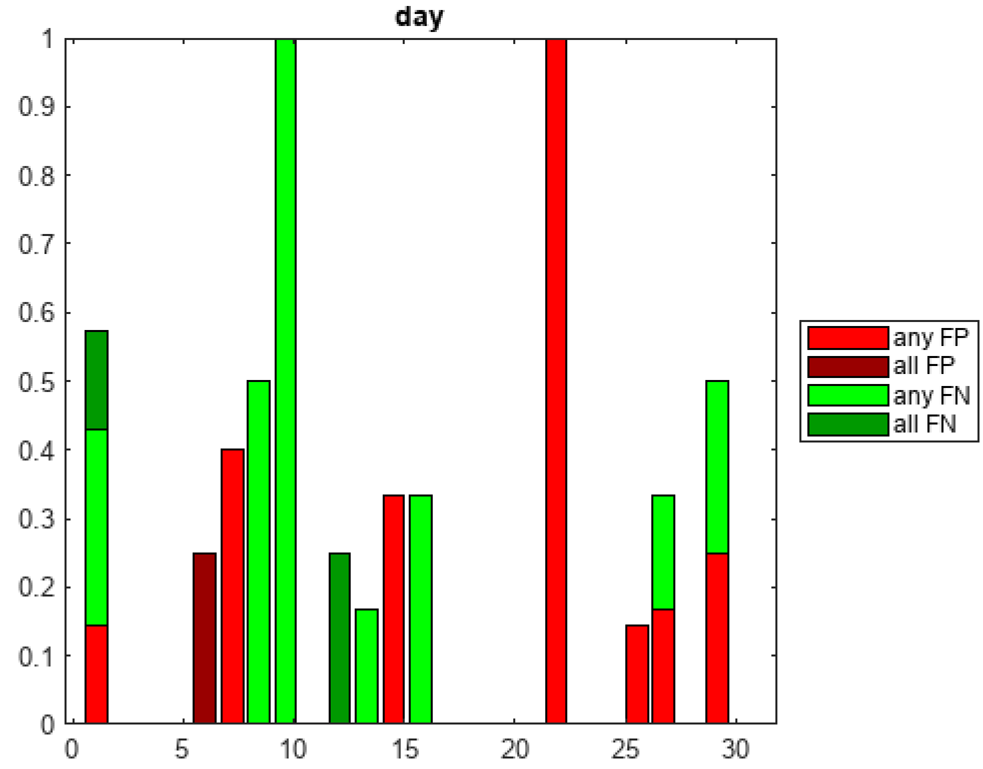

default
0.25
0.2
0.15
0.1
0.05
0
no
any FP
all FP
any FN
all FN

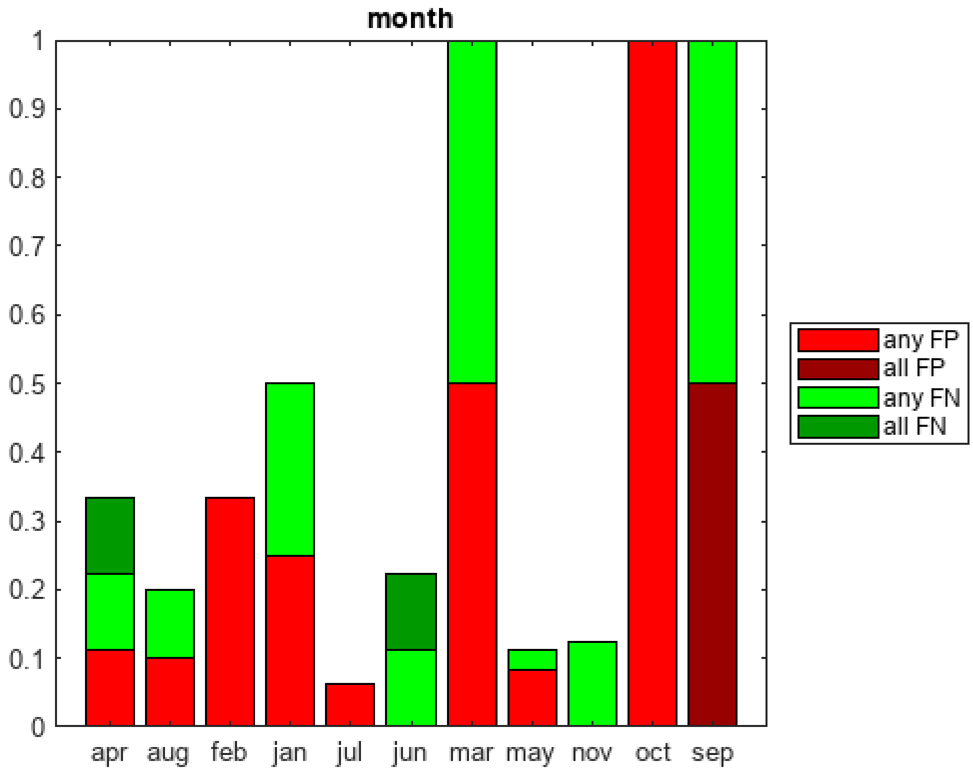

balance
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
2
4
6
8
10
any FP
all FP
any FN
all FN

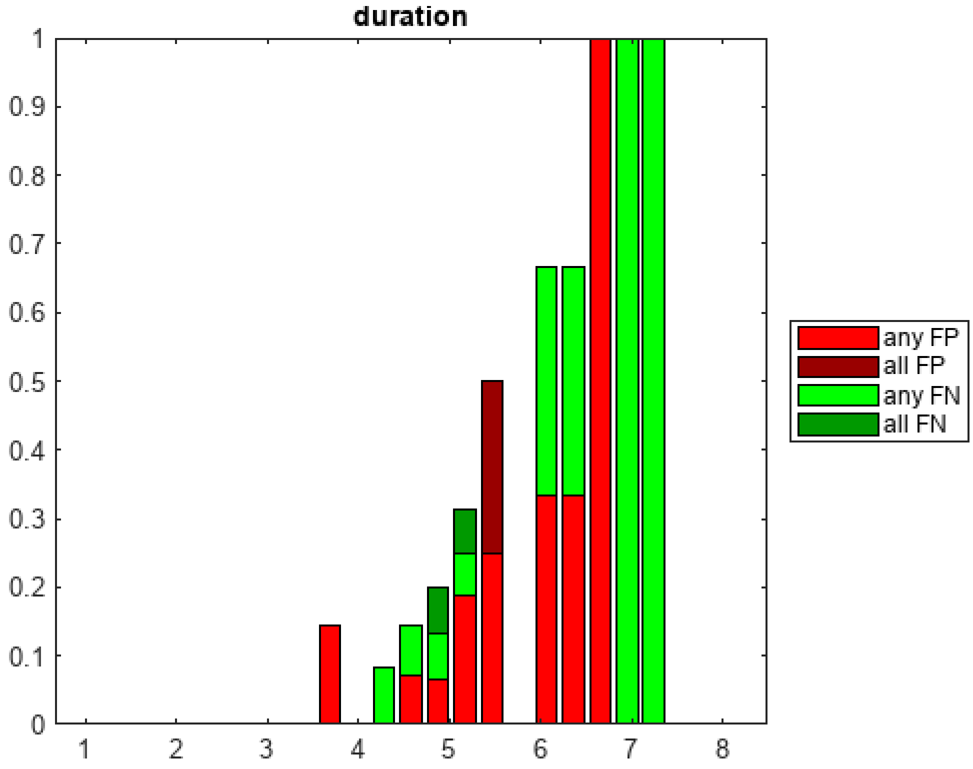

housing
0.3
0.25
0.2
0.15
0.1
0.05
0
no
yes
any FP
all FP
any FN
all FN

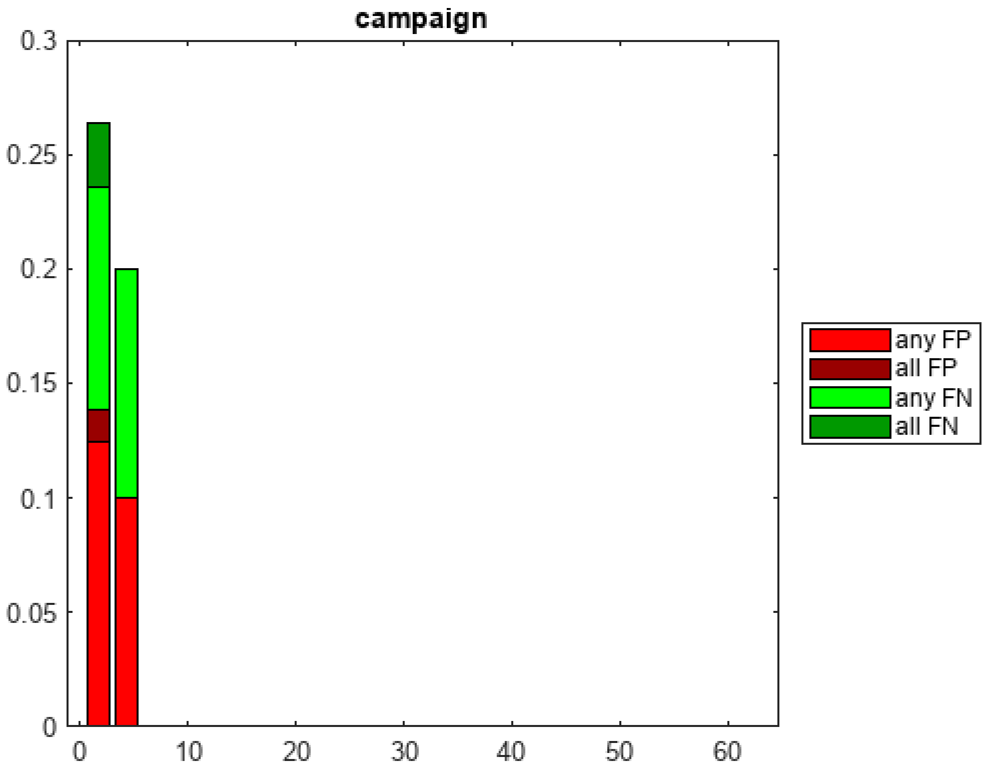

loan
0.25
0.2
0.15
0.1
0.05
0
no
yes
any FP
all FP
any FN
all FN

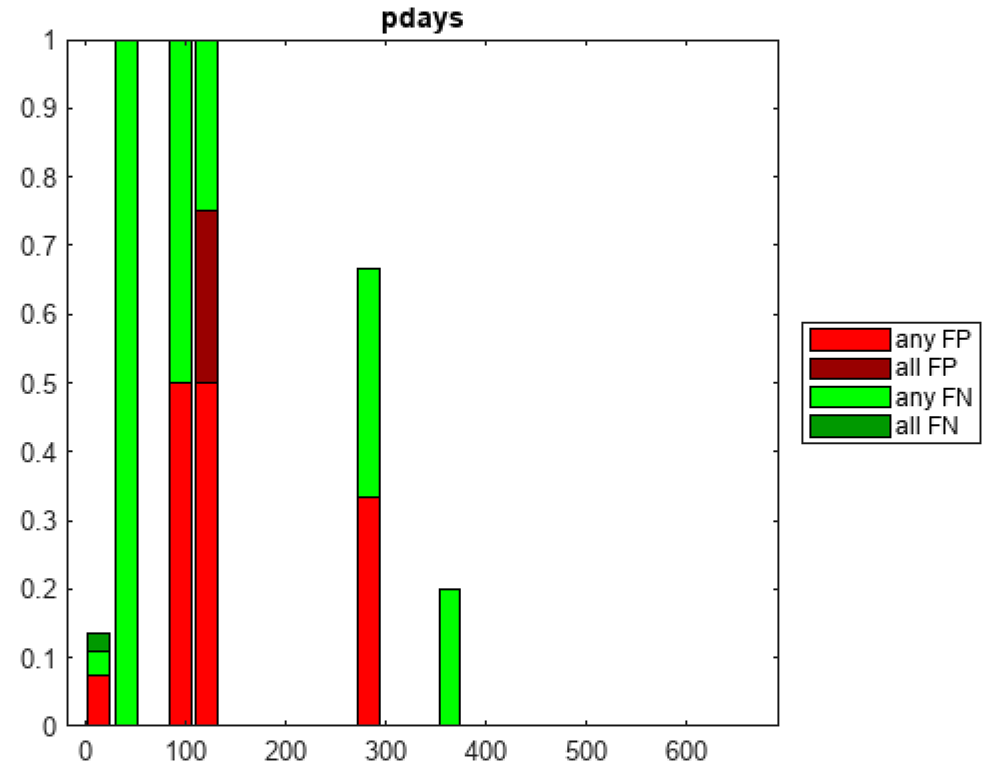

contact
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
cellular
telephone
unknown
any FP
all FP
any FN
all FN

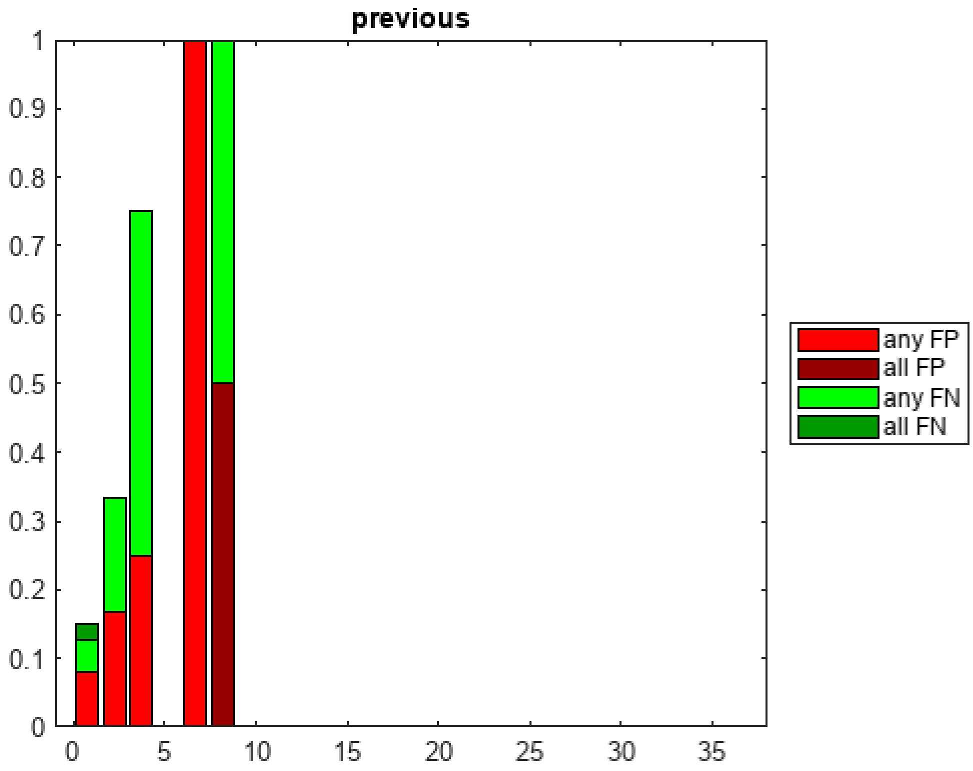

day
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
5
10
15
20
25
30
any FP
all FP
any FN
all FN

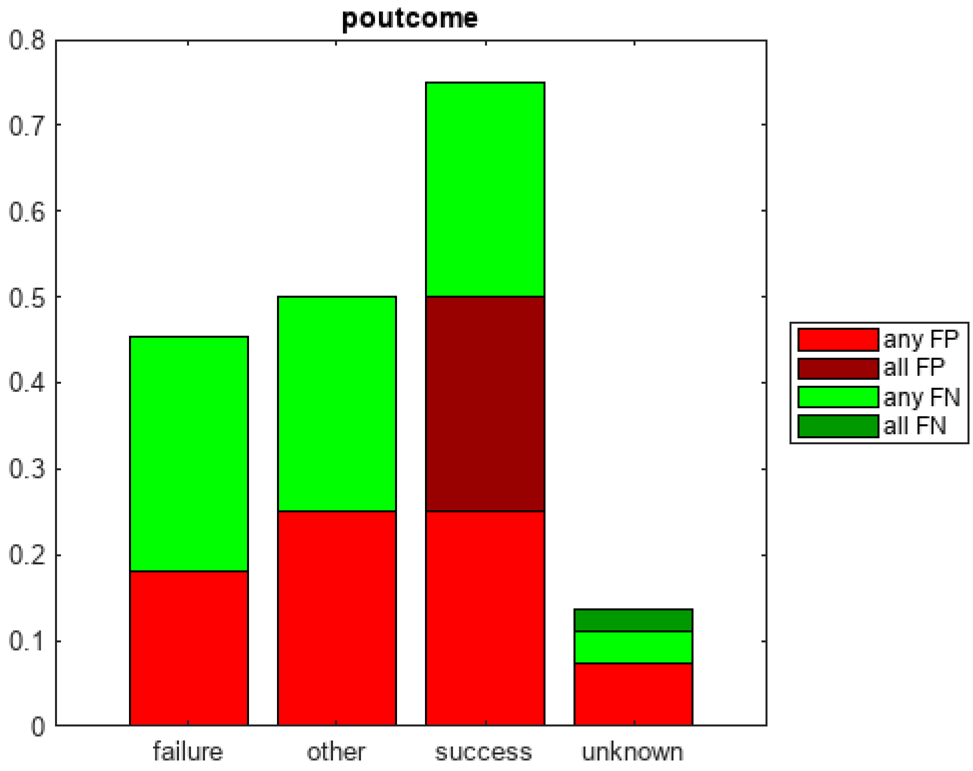

month
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
apr
aug
feb
jan
jul
jun
mar
may
nov
oct
sep
any FP
all FP
any FN
all FN

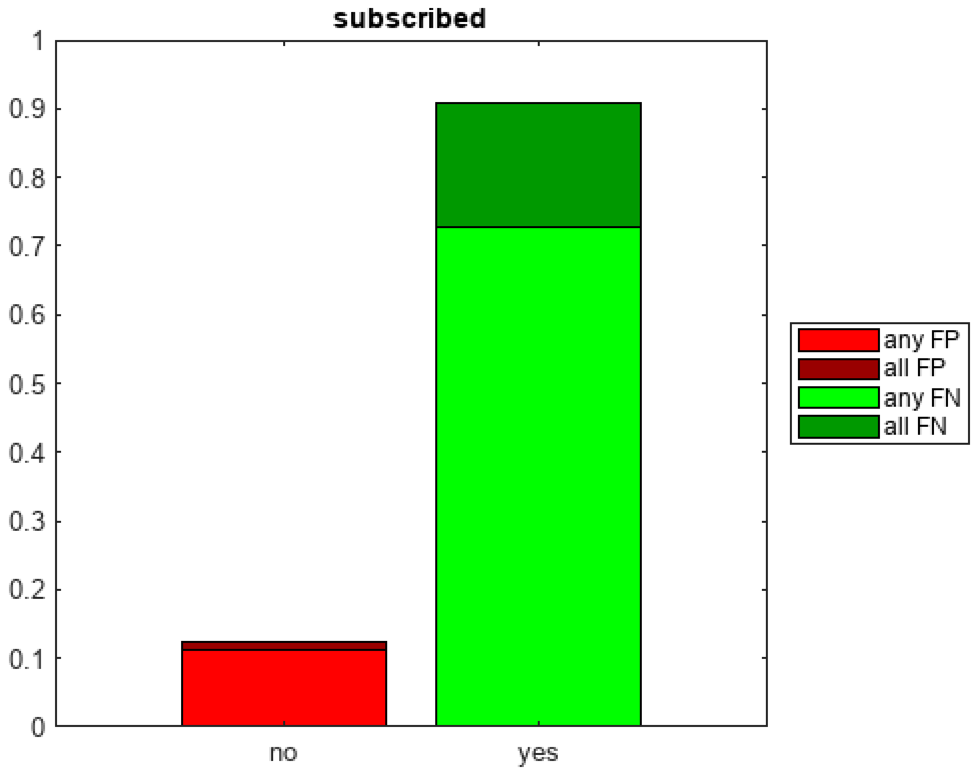

duration
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1
2
3
4
5
6
7
8
any FP
all FP
any FN
all FN

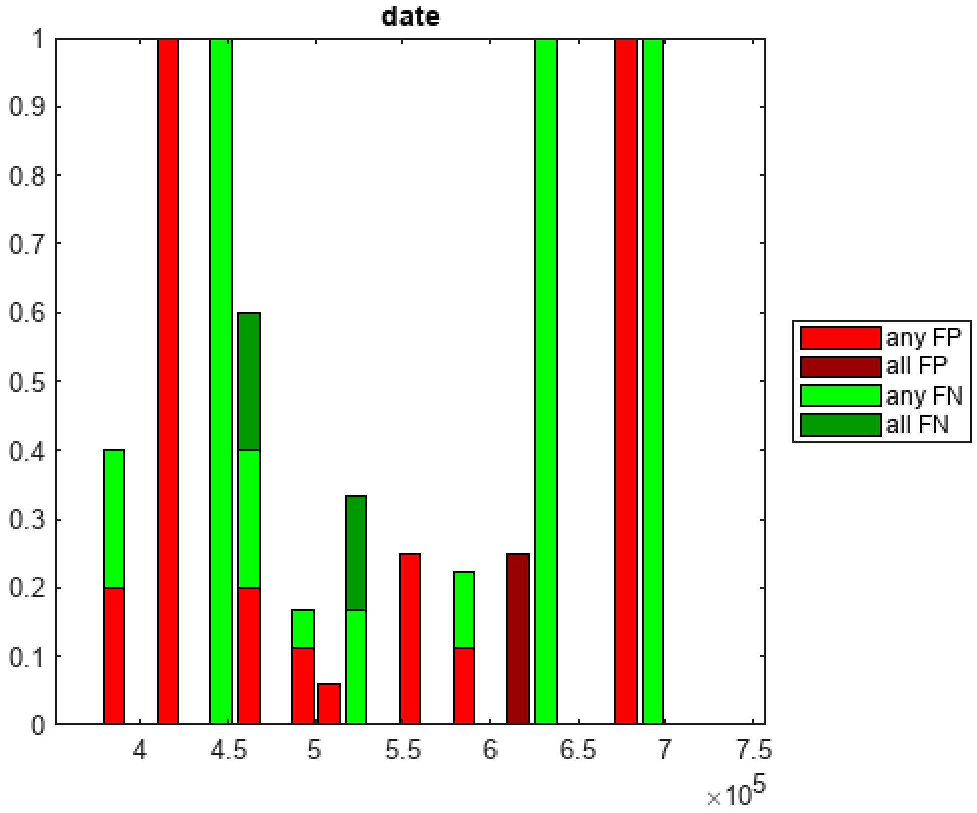

campaign
0.3
0.25
0.2
0.15
0.1
0.05
0
0
10
20
30
40
50
60
🟥 any FP
🟥 all FP
🟩 any FN
🟩 all FN


pdays
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
100
200
300
400
500
600
🟥 any FP
🟥 all FP
🟩 any FN
🟩 all FN


previous
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
5
10
15
20
25
30
35
any FP
all FP
any FN
all FN


poutcome
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
failure
other
success
unknown
any FP
all FP
any FN
all FN


subscribed
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
no
yes
any FP
all FP
any FN
all FN


date
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
4
4.5
5
5.5
6
6.5
7
7.5
$\times 10^5$
any FP
all FP
any FN
all FN