Classification using Decision Trees and Rules

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Identifying risky bank loans using C5.0 decision tree algorithm

Note: C5.0 Decision Tree Algorithm was developed by J Ross Quinlan.

Decision tree is a classifier which utilizes a tree structure to model relationships among features and potential outcomes.

Decision trees have three main parts: a root node, leaf nodes and branches. The root node is the starting point of the tree, and both root and leaf nodes contain questions or criteria to be answered. Branches are arrows connecting nodes, showing the flow from question to answer. Each node typically has two or more nodes extending from it. For example, if the question in the first node requires a "yes" or "no" answer, there will be one leaf node for a "yes" response, and another node for "no." And at the end we have terminal nodes.

After the model is created, many decision tree algorithms output the resulting structure in a human-readable format. This provides tremendous insight into how and why the model works or doesn't work well for a particular task. This also makes decision trees particularly appropriate for applications in which the classification mechanism needs to be transparent for legal reasons, or in case the results need to be shared with others in order to inform future business practices.

Example of potential uses: credit scoring models, marketing studies of customer behaviour (churn or satisfaction level), diagnosis of medical conditions.

Decision trees can be used for models of any type (in general). However there are scenarios where decision trees don't work well. For example a task with many nominal features with many levels or a task with too many numeric features. These cases may result in very complex decision trees.

An algorithm known as recursive partitioning is the key to the nonparametric statistical method of classification and regression trees (CART) (Breiman, Friedman, Olshen, and Stone, 1984). Recursive partitioning is the step-by-step process by which a decision tree is constructed by either splitting or not splitting each node on the tree into two daughter nodes. An attractive feature of the CART methodology is that because the algorithm asks a sequence of hierarchical Boolean questions (e.g., is a given point less than a threshold value), it is relatively simple to understand and interpret the results.

The algorithm stops once the data is sufficiently homogenous or a stop criteria has been met. So your data splits at every decision node. It is more like the algorithm trying to divide and conquer.

When will the tree stop growing? when all nodes have same class OR no remaining features to distinguish in the split dataset (say 80% of examples in each group are from a single class) OR tree has grown to predifined size limit.

Caution- Do not try to overfit the data.

The C5.0 Algorithm

Pros: all purpose classifier, highly automatic learning process that can handle numeric or nominal features along with missing data, excludes unimportant features

Cons: decision tree models biased toward splits on features having a large number of levels, it is easy to overfit or underfit, can have trouble modeling some relationships due to reliance on axis-parallel splits, small changes in training data results in large changes to decision logic, large trees are difficult to interpret and decisions they make may seem counterintuitive

Q. How to choose the best split? First obstacle is to identify which feature to split upon. Purity is the degree to which a subset of examples contains only a single class. Any subset composed only of a single class is called pure.

Concept of Entropy: Entropy checks the purity in the dataset. It quantifies randomness in a set. The decision trees tend to find splits that reduce entropy. Entropy is measured in bits. There are two possible classes of entropy. One class ranges from 0 to 1 and in another class, entropy for n classes range from 0 to log(base2)n. Minimum value indicates the sample is completely homogenous and maximum indicates complete diversity.

Information gain: To use entropy to determine optimal feature to split upon, the algorithm calculates the change in homogeneity that would result from a split on each possible feature. Information gain for a feature is the difference between entropy in the segment before the split and the partitions resulting from the split.

The higher the information gain, the better a feature is at creating homogeneous groups after a split on this feature. If the information gain is zero, there is no reduction in entropy for splitting on this feature. On the other hand, the maximum information gain is equal to the entropy prior to the split. This would imply that the entropy after the split is zero, which means that the split results in completely homogeneous groups.

The previous formulae assume nominal features, but decision trees use information gain for splitting on numeric features as well. To do so, a common practice is to test various splits that divide the values into groups greater than or less than a numeric threshold. This reduces the numeric feature into a two-level categorical feature that allows information gain to be calculated as usual. The numeric cut point yielding the largest information gain is chosen for the split.

Though it is used by C5.0, information gain is not the only splitting criterion that can be used to build decision trees. Other commonly used criteria are Gini index, Chi-Squared statistic, and gain ratio.

Pruning the decision tree: if the tree grows overly large, many of the decisions it makes will be overly specific and the model will be over tted to the training data. The process of pruning a decision tree involves reducing its size such that it generalizes better to unseen data.

One solution to this problem is to stop the tree from growing once it reaches a certain number of decisions or when the decision nodes contain only a small number of examples. This is called early stopping or pre-pruning the decision tree. As the tree avoids doing needless work, this is an appealing strategy. However, one downside to this approach is that there is no way to know whether the tree will miss subtle, but important patterns that it would have learned had it grown to a larger size.

An alternative, called post-pruning, involves growing a tree that is intentionally too large and pruning leaf nodes to reduce the size of the tree to a more appropriate level. This is often a more effective approach than pre-pruning, because it is quite dif cult to determine the optimal depth of a decision tree without growing it rst. Pruning the tree later on allows the algorithm to be certain that all the important data structures were discovered.

One of the bene ts of the C5.0 algorithm is that it is opinionated about pruning it takes care of many decisions automatically using fairly reasonable defaults. Its overall strategy is to post-prune the tree. It first grows a large tree that over ts the training data. Later, the nodes and branches that have little effect on the classi cation errors are removed. In some cases, entire branches are moved further up the tree or replaced by simpler decisions. These processes of grafting branches are known as subtree raising and subtree replacement, respectively.

```r
credit_data<-read.csv("~/Desktop/Decision Trees C5 Algorithm/credit.csv")
#Source: the UCI Machine Learning Data Repository
# http://archive.ics.uci.edu/ml by Hans Hofmann of the University of Hamburg
str(credit_data)
```

```
## 'data.frame':    1000 obs. of  21 variables:
##  $ checking_balance    : Factor w/ 4 levels "< 0 DM","> 200 DM",..: 1 3 4 1 1 4 4 3 4 3 ...
##  $ months_loan_duration: int  6 48 12 42 24 36 24 36 12 30 ...
##  $ credit_history      : Factor w/ 5 levels "critical","delayed",..: 1 5 1 5 2 5 5 5 5 1 ...
```

```
## $ purpose            : Factor w/ 10 levels "business","car (new)",..: 8 8 5 6 2 5 6 3 8 2 ...
## $ amount             : int   1169 5951 2096 7882 4870 9055 2835 6948 3059 5234 ...
## $ savings_balance    : Factor w/ 5 levels "< 100 DM","> 1000 DM",..: 5 1 1 1 1 5 4 1 2 1 ...
## $ employment_length  : Factor w/ 5 levels "> 7 yrs","0 - 1 yrs",..: 1 3 4 4 3 3 1 3 4 5 ...
## $ installment_rate   : int   4 2 2 2 3 2 3 2 2 4 ...
## $ personal_status    : Factor w/ 4 levels "divorced male",..: 4 2 4 4 4 4 4 4 1 3 ...
## $ other_debtors      : Factor w/ 3 levels "co-applicant",..: 3 3 3 2 3 3 3 3 3 3 ...
## $ residence_history  : int   4 2 3 4 4 4 4 2 4 2 ...
## $ property           : Factor w/ 4 levels "building society savings",..: 3 3 3 1 4 4 1 2 3 2 ...
## $ age                : int   67 22 49 45 53 35 53 35 61 28 ...
## $ installment_plan   : Factor w/ 3 levels "bank","none",..: 2 2 2 2 2 2 2 2 2 2 ...
## $ housing            : Factor w/ 3 levels "for free","own",..: 2 2 2 1 1 1 2 3 2 2 ...
## $ existing_credits   : int   2 1 1 1 2 1 1 1 1 2 ...
## $ default            : int   1 2 1 1 2 1 1 1 1 2 ...
## $ dependents         : int   1 1 2 2 2 2 1 1 1 1 ...
## $ telephone          : Factor w/ 2 levels "none","yes": 2 1 1 1 1 2 1 2 1 1 ...
## $ foreign_worker     : Factor w/ 2 levels "no","yes": 2 2 2 2 2 2 2 2 2 2 ...
## $ job                : Factor w/ 4 levels "mangement self-employed",..: 2 2 4 2 2 4 2 1 4 1 ...
```

```r
#notice DM in checking_balance column is in Deutsche Marks
#notice that columns 18 to 21 are not needed for analysis
#because they provide additional user information
library(dplyr)
```

```
##
## Attaching package: 'dplyr'

## The following objects are masked from 'package:stats':
##
##     filter, lag

## The following objects are masked from 'package:base':
##
##     intersect, setdiff, setequal, union
```

```r
credit_data<-credit_data %>% select(-18,-19,-20,-21)
#we are converting default column to factor as the label column in C5.0 algorithm has to be a factor
credit_data$default<-as.factor(credit_data$default)

#Exploring data
table(credit_data$checking_balance)
```

```
##
##    < 0 DM   > 200 DM 1 - 200 DM    unknown
##       274         63        269        394
```

```r
table(credit_data$savings_balance)
```

```
##
##    < 100 DM   > 1000 DM  101 - 500 DM 501 - 1000 DM       unknown
##         603          48          103            63           183
```

```r
summary(credit_data$months_loan_duration)
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##     4.0    12.0    18.0    20.9    24.0    72.0
```

```r
summary(credit_data$amount)
```

```
##     Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##     250    1366    2320    3271    3972   18424
```

```
table(credit_data$default)
```

```
##
##   1   2
## 700 300
```

```
#Data Preparation: creating training and test datasets
#we will first randomize the dataset
#sample() function is used to perform random sampling
#seed value causes the randomization process to follow a sequence that can be replicated later on if de
set.seed(123)
train_data <- sample(1000, 900)
#the resulting train_sample object is a vector of 900 random integers
str(train_data)
```

```
##  int [1:900] 288 788 409 881 937 46 525 887 548 453 ...
```

```
training<- credit_data[train_data,]
testing<- credit_data[-train_data,]
```

```
#to check consistency in training and testing credit data
prop.table(table(training$default))
```

```
##
##          1          2
## 0.7033333 0.2966667
```

```
prop.table(table(testing$default))
```

```
##
##    1    2
## 0.67 0.33
```

```
#data seems to be fairly evenly split
```

Training the data on model

```
#load library to run C5.0 algorithm
library(C50)
```

```
## Warning: package 'C50' was built under R version 3.4.3
```

```
credit_model <- C5.0(training[-17], training$default)
```

```
## Warning in as.POSIXlt.POSIXct(x, tz): unknown timezone 'zone/tz/2017c.1.0/
## zoneinfo/Europe/Madrid'
```

```
#The input C5.0(training data, class for each row in training data,
#trials to control boosting iterations: set to 1 by default,costs is
#associated with certain errors)
print(credit_model)
```

```
##
## Call:
## C5.0.default(x = training[-17], y = training$default)
##
## Classification Tree
```

```
## Number of samples: 900
## Number of predictors: 16
##
## Tree size: 83
##
## Non-standard options: attempt to group attributes
```

summary(credit_model) *#to see tree decisions*

```
##
## Call:
## C5.0.default(x = training[-17], y = training$default)
##
##
## C5.0 [Release 2.07 GPL Edition]      Wed Jan 17 16:02:14 2018
## -----------------------------
##
## Class specified by attribute `outcome'
##
## Read 900 cases (17 attributes) from undefined.data
##
## Decision tree:
##
## checking_balance in {> 200 DM,unknown}: 1 (412/50)
## checking_balance in {< 0 DM,1 - 200 DM}:
## :...other_debtors = guarantor:
##     :...months_loan_duration > 36: 2 (4/1)
##     :   months_loan_duration <= 36:
##     :   :...installment_plan in {none,stores}: 1 (24)
##     :       installment_plan = bank:
##     :       :...purpose = car (new): 2 (3)
##     :           purpose in {business,car (used),domestic appliances,education,
##     :                       furniture,others,radio/tv,repairs,
##     :                       retraining}: 1 (7/1)
##     other_debtors in {co-applicant,none}:
##     :...credit_history = fully repaid: 2 (27/6)
##         credit_history = critical:
##         :...savings_balance in {> 1000 DM,unknown}: 1 (13/1)
##         :   savings_balance = 101 - 500 DM:
##         :   :...installment_plan = bank: 2 (1)
##         :   :   installment_plan in {none,stores}: 1 (6)
##         :   savings_balance = 501 - 1000 DM:
##         :   :...months_loan_duration <= 21: 1 (3)
##         :   :   months_loan_duration > 21: 2 (2)
##         :   savings_balance = < 100 DM:
##         :   :...months_loan_duration <= 22: 1 (51/11)
##         :       months_loan_duration > 22:
##         :       :...age <= 32: 2 (11/1)
##         :           age > 32:
##         :           :...months_loan_duration <= 45: 1 (13/3)
##         :               months_loan_duration > 45: 2 (2)
##         credit_history = fully repaid this bank:
##         :...other_debtors = co-applicant: 1 (2)
##         :   other_debtors = none:
```

```
##          :    :...property in {building society savings,
##          :    :                unknown/none}: 2 (14/1)
##          :        property = real estate:
##          :        :...personal_status = female: 2 (1)
##          :        :   personal_status in {divorced male,married male,
##          :        :                single male}: 1 (3)
##          :        property = other:
##          :        :...checking_balance = 1 - 200 DM: 1 (2)
##          :            checking_balance = < 0 DM:
##          :            :...personal_status = married male: 1 (1)
##          :                personal_status in {divorced male,female,
##          :                                single male}: 2 (5/1)
##      credit_history in {delayed,repaid}:
##      :...savings_balance = 501 - 1000 DM: 1 (10/2)
##          savings_balance = > 1000 DM:
##          :...credit_history = delayed: 2 (1)
##          :   credit_history = repaid: 1 (8)
##          savings_balance = 101 - 500 DM:
##          :...other_debtors = co-applicant: 2 (3)
##          :   other_debtors = none:
##          :   :...personal_status in {divorced male,
##          :   :                married male}: 2 (6/1)
##          :       personal_status = female:
##          :       :...installment_rate <= 3: 1 (4/1)
##          :       :   installment_rate > 3: 2 (4)
##          :       personal_status = single male:
##          :       :...age <= 41: 1 (15/2)
##          :           age > 41: 2 (2)
##          savings_balance = unknown:
##          :...credit_history = delayed: 1 (8)
##          :   credit_history = repaid:
##          :   :...checking_balance = < 0 DM:
##          :       :...employment_length in {0 - 1 yrs,
##          :       :   :                unemployed}: 1 (2)
##          :       :   employment_length = 1 - 4 yrs: 2 (5)
##          :       :   employment_length = > 7 yrs:
##          :       :   :...amount <= 4657: 1 (5/2)
##          :       :   :   amount > 4657: 2 (3)
##          :       :   employment_length = 4 - 7 yrs:
##          :       :   :...months_loan_duration <= 22: 1 (3)
##          :       :       months_loan_duration > 22: 2 (2)
##          :       checking_balance = 1 - 200 DM:
##          :       :...residence_history > 3: 1 (9)
##          :           residence_history <= 3:
##          :           :...property in {building society savings,
##          :           :                unknown/none}: 2 (4)
##          :               property = other: 1 (6)
##          :               property = real estate:
##          :               :...purpose in {business,car (new),car (used),
##          :               :                domestic appliances,education,
##          :               :                others,repairs,retraining}: 1 (2)
##          :                   purpose in {furniture,radio/tv}: 2 (2)
##      savings_balance = < 100 DM:
##      :...months_loan_duration > 39:
```

```
##                         :...residence_history <= 1: 1 (2)
##                         :   residence_history > 1: 2 (19/1)
##                     months_loan_duration <= 39:
##                     :...purpose in {domestic appliances,others}: 1 (3)
##                         purpose = retraining: 2 (1)
##                         purpose = car (used):
##                         :...amount <= 8086: 1 (9/1)
##                         :   amount > 8086: 2 (5)
##                         purpose = education:
##                         :...checking_balance = < 0 DM: 2 (5)
##                         :   checking_balance = 1 - 200 DM: 1 (2)
##                         purpose = repairs:
##                         :...residence_history <= 3: 2 (4/1)
##                         :   residence_history > 3: 1 (3)
##                         purpose = business:
##                         :...credit_history = delayed: 2 (2)
##                         :   credit_history = repaid:
##                         :   :...age <= 34: 1 (5)
##                         :       age > 34: 2 (2)
##                         purpose = car (new):
##                         :...employment_length in {> 7 yrs,4 - 7 yrs}: 2 (16/4)
##                         :   employment_length = unemployed:
##                         :   :...credit_history = delayed: 2 (2)
##                         :   :   credit_history = repaid: 1 (3)
##                         :   employment_length = 0 - 1 yrs:
##                         :   :...personal_status in {divorced male,female,
##                         :   :   :                   married male}: 2 (7)
##                         :   :   personal_status = single male:
##                         :   :   :...residence_history <= 2: 2 (4/1)
##                         :   :       residence_history > 2: 1 (2)
##                         :   employment_length = 1 - 4 yrs:
##                         :   :...installment_rate <= 2: 1 (3)
##                         :       installment_rate > 2:
##                         :       :...installment_rate <= 3: 2 (4)
##                         :           installment_rate > 3: [S1]
##                     purpose = furniture:
##                     :...residence_history <= 1: 1 (8/1)
##                     :   residence_history > 1:
##                     :   :...checking_balance = 1 - 200 DM:
##                     :       :...housing in {for free,own}: 2 (7/1)
##                     :       :   housing = rent: 1 (1)
##                     :       checking_balance = < 0 DM:
##                     :       :...installment_rate > 3: 2 (10/3)
##                     :           installment_rate <= 3:
##                     :           :...age <= 21: 2 (2)
##                     :               age > 21: 1 (12/2)
##                     purpose = radio/tv:
##                     :...employment_length = 4 - 7 yrs: 1 (3)
##                         employment_length = unemployed: 2 (1)
##                         employment_length = > 7 yrs:
##                         :...amount <= 932: 2 (2)
##                         :   amount > 932: 1 (7)
##                         employment_length = 1 - 4 yrs:
##                         :...months_loan_duration <= 15: 1 (6)
```

```
##                                 :      months_loan_duration > 15:
##                                 :      :...amount <= 3275: 2 (7)
##                                 :            amount > 3275: 1 (2)
##                              employment_length = 0 - 1 yrs:
##                              :...age <= 25: 2 (5)
##                                   age > 25:
##                                   :...checking_balance = 1 - 200 DM: 1 (3)
##                                        checking_balance = < 0 DM:
##                                        :...months_loan_duration <= 21: 1 (2)
##                                             months_loan_duration > 21: 2 (3)
##
## SubTree [S1]
##
## property = other: 2 (1)
## property in {building society savings,real estate,unknown/none}: 1 (4/1)
##
##
## Evaluation on training data (900 cases):
##
##        Decision Tree
##      ----------------
##      Size        Errors
##
##        83  100(11.1%)   <<
##
##
##      (a)   (b)     <-classified as
##      ----  ----
##      611    22     (a): class 1
##       78   189     (b): class 2
##
##
##   Attribute usage:
##
##   100.00% checking_balance
##    54.22% other_debtors
##    50.00% credit_history
##    43.89% savings_balance
##    34.89% months_loan_duration
##    20.22% purpose
##    11.89% employment_length
##    10.78% residence_history
##     8.56% age
##     6.00% personal_status
##     5.00% property
##     4.89% installment_rate
##     4.56% installment_plan
##     4.44% amount
##     0.89% housing
##
##
## Time: 0.0 secs
```

Sometimes a tree results in decisions that make little logical sense. For example, why would an applicant whose credit history is very good be likely to default, while those whose checking balance is unknown are not likely to default? Contradictory rules like this occur sometimes. They might re ect a real pattern in the data, or they may be a statistical anomaly. In either case, it is important to investigate such strange decisions to see whether the tree's logic makes sense for business use.

Test dataset performance

```
credit_predict <- predict(credit_model, testing)
#predict function takes the training model, testing subdata, prob/class display
```

```
library(gmodels)
CrossTable(testing$default, credit_predict, prop.chisq = FALSE, prop.c = FALSE, prop.r = FALSE, dnn = c
```

```
##
##
##    Cell Contents
## |-------------------------|
## |                       N |
## |          N / Table Total |
## |-------------------------|
##
##
## Total Observations in Table:  100
##
##
##               | predicted default
## actual default |         1 |         2 | Row Total |
## ---------------|-----------|-----------|-----------|
##             1 |        61 |         6 |        67 |
##               |     0.610 |     0.060 |           |
## ---------------|-----------|-----------|-----------|
##             2 |        19 |        14 |        33 |
##               |     0.190 |     0.140 |           |
## ---------------|-----------|-----------|-----------|
##    Column Total |        80 |        20 |       100 |
## ---------------|-----------|-----------|-----------|
##
##
```

Boosting One way the C5.0 algorithm improved upon the C4.5 algorithm was through the addition of adaptive boosting. This is a process in which many decision trees are built and the trees vote on the best class for each example. Boosting can be applied to any machine learning algorithm.

The C5.0() function makes it easy to add boosting to our C5.0 decision tree. We simply need to add an additional trials parameter indicating the number of separate decision trees to use in the boosted team. The trials parameter sets an upper limit; the algorithm will stop adding trees if it recognizes that additional trials do not seem to be improving the accuracy. We'll start with 10 trials, a number that has become the de facto standard, as research suggests that this reduces error rates on test data by about 25 percent

Improving the model with boosting:

```
credit_boost10 <- C5.0(training[-17], training$default, trials = 30)
print(credit_boost10)
```

```
##
## Call:
## C5.0.default(x = training[-17], y = training$default, trials = 30)
##
## Classification Tree
## Number of samples: 900
## Number of predictors: 16
##
## Number of boosting iterations: 30
## Average tree size: 64.3
##
## Non-standard options: attempt to group attributes
```

```
#we can already observe that the tree length has come down to 62 decisions
summary(credit_boost10) #classifier made only 7 mistakes
```

```
##
## Call:
## C5.0.default(x = training[-17], y = training$default, trials = 30)
##
##
## C5.0 [Release 2.07 GPL Edition]      Wed Jan 17 16:02:14 2018
## -------------------------------
##
## Class specified by attribute `outcome'
##
## Read 900 cases (17 attributes) from undefined.data
##
## -----  Trial 0:  -----
##
## Decision tree:
##
## checking_balance in {> 200 DM,unknown}: 1 (412/50)
## checking_balance in {< 0 DM,1 - 200 DM}:
## :...other_debtors = guarantor:
##     :...months_loan_duration > 36: 2 (4/1)
##     :   months_loan_duration <= 36:
##     :   :...installment_plan in {none,stores}: 1 (24)
##     :       installment_plan = bank:
##     :       :...purpose = car (new): 2 (3)
##     :           purpose in {business,car (used),domestic appliances,education,
##     :                       furniture,others,radio/tv,repairs,
##     :                       retraining}: 1 (7/1)
##     other_debtors in {co-applicant,none}:
##     :...credit_history = fully repaid: 2 (27/6)
##         credit_history = critical:
##         :...savings_balance in {> 1000 DM,unknown}: 1 (13/1)
##         :   savings_balance = 101 - 500 DM:
##         :   :...installment_plan = bank: 2 (1)
##         :   :   installment_plan in {none,stores}: 1 (6)
```

```
##              :    savings_balance = 501 - 1000 DM:
##              :    :...months_loan_duration <= 21: 1 (3)
##              :    :   months_loan_duration > 21: 2 (2)
##              :    savings_balance = < 100 DM:
##              :    :...months_loan_duration <= 22: 1 (51/11)
##              :        months_loan_duration > 22:
##              :        :...age <= 32: 2 (11/1)
##              :            age > 32:
##              :            :...months_loan_duration <= 45: 1 (13/3)
##              :                months_loan_duration > 45: 2 (2)
##          credit_history = fully repaid this bank:
##          :...other_debtors = co-applicant: 1 (2)
##          :   other_debtors = none:
##          :   :...property in {building society savings,
##          :   :              unknown/none}: 2 (14/1)
##          :       property = real estate:
##          :       :...personal_status = female: 2 (1)
##          :       :   personal_status in {divorced male,married male,
##          :       :                       single male}: 1 (3)
##          :       property = other:
##          :       :...checking_balance = 1 - 200 DM: 1 (2)
##          :           checking_balance = < 0 DM:
##          :           :...personal_status = married male: 1 (1)
##          :               personal_status in {divorced male,female,
##          :                                   single male}: 2 (5/1)
##          credit_history in {delayed,repaid}:
##          :...savings_balance = 501 - 1000 DM: 1 (10/2)
##              savings_balance = > 1000 DM:
##              :...credit_history = delayed: 2 (1)
##              :   credit_history = repaid: 1 (8)
##              savings_balance = 101 - 500 DM:
##              :...other_debtors = co-applicant: 2 (3)
##              :   other_debtors = none:
##              :   :...personal_status in {divorced male,
##              :       :                   married male}: 2 (6/1)
##              :       personal_status = female:
##              :       :...installment_rate <= 3: 1 (4/1)
##              :       :   installment_rate > 3: 2 (4)
##              :       personal_status = single male:
##              :       :...age <= 41: 1 (15/2)
##              :           age > 41: 2 (2)
##              savings_balance = unknown:
##              :...credit_history = delayed: 1 (8)
##              :   credit_history = repaid:
##              :   :...checking_balance = < 0 DM:
##              :       :...employment_length in {0 - 1 yrs,
##              :       :   :                     unemployed}: 1 (2)
##              :       :   employment_length = 1 - 4 yrs: 2 (5)
##              :       :   employment_length = > 7 yrs:
##              :       :   :...amount <= 4657: 1 (5/2)
##              :       :   :   amount > 4657: 2 (3)
##              :       :   employment_length = 4 - 7 yrs:
##              :       :   :...months_loan_duration <= 22: 1 (3)
##              :       :       months_loan_duration > 22: 2 (2)
```

```
##               :          checking_balance = 1 - 200 DM:
##               :          :...residence_history > 3: 1 (9)
##               :              residence_history <= 3:
##               :              :...property in {building society savings,
##               :              :               unknown/none}: 2 (4)
##               :                  property = other: 1 (6)
##               :                  property = real estate:
##               :                  :...purpose in {business,car (new),car (used),
##               :                  :              domestic appliances,education,
##               :                  :              others,repairs,retraining}: 1 (2)
##               :                      purpose in {furniture,radio/tv}: 2 (2)
##           savings_balance = < 100 DM:
##           :...months_loan_duration > 39:
##               :...residence_history <= 1: 1 (2)
##               :   residence_history > 1: 2 (19/1)
##               months_loan_duration <= 39:
##               :...purpose in {domestic appliances,others}: 1 (3)
##                   purpose = retraining: 2 (1)
##                   purpose = car (used):
##                   :...amount <= 8086: 1 (9/1)
##                   :   amount > 8086: 2 (5)
##                   purpose = education:
##                   :...checking_balance = < 0 DM: 2 (5)
##                   :   checking_balance = 1 - 200 DM: 1 (2)
##                   purpose = repairs:
##                   :...residence_history <= 3: 2 (4/1)
##                   :   residence_history > 3: 1 (3)
##                   purpose = business:
##                   :...credit_history = delayed: 2 (2)
##                   :   credit_history = repaid:
##                   :   :...age <= 34: 1 (5)
##                   :       age > 34: 2 (2)
##                   purpose = car (new):
##                   :...employment_length in {> 7 yrs,4 - 7 yrs}: 2 (16/4)
##                   :   employment_length = unemployed:
##                   :   :...credit_history = delayed: 2 (2)
##                   :   :   credit_history = repaid: 1 (3)
##                   :   employment_length = 0 - 1 yrs:
##                   :   :...personal_status in {divorced male,female,
##                   :   :   :                   married male}: 2 (7)
##                   :   :   personal_status = single male:
##                   :   :   :...residence_history <= 2: 2 (4/1)
##                   :   :       residence_history > 2: 1 (2)
##                   :   employment_length = 1 - 4 yrs:
##                   :   :...installment_rate <= 2: 1 (3)
##                   :       installment_rate > 2:
##                   :       :...installment_rate <= 3: 2 (4)
##                   :           installment_rate > 3: [S1]
##               purpose = furniture:
##               :...residence_history <= 1: 1 (8/1)
##               :   residence_history > 1:
##               :   :...checking_balance = 1 - 200 DM:
##               :       :...housing in {for free,own}: 2 (7/1)
##               :       :   housing = rent: 1 (1)
```

```
##                        :           checking_balance = < 0 DM:
##                        :           :...installment_rate > 3: 2 (10/3)
##                        :               installment_rate <= 3:
##                        :               :...age <= 21: 2 (2)
##                        :                   age > 21: 1 (12/2)
##                  purpose = radio/tv:
##                  :...employment_length = 4 - 7 yrs: 1 (3)
##                      employment_length = unemployed: 2 (1)
##                      employment_length = > 7 yrs:
##                      :...amount <= 932: 2 (2)
##                      :   amount > 932: 1 (7)
##                      employment_length = 1 - 4 yrs:
##                      :...months_loan_duration <= 15: 1 (6)
##                      :   months_loan_duration > 15:
##                      :   :...amount <= 3275: 2 (7)
##                      :       amount > 3275: 1 (2)
##                      employment_length = 0 - 1 yrs:
##                      :...age <= 25: 2 (5)
##                          age > 25:
##                          :...checking_balance = 1 - 200 DM: 1 (3)
##                              checking_balance = < 0 DM:
##                              :...months_loan_duration <= 21: 1 (2)
##                                  months_loan_duration > 21: 2 (3)
##
## SubTree [S1]
##
## property = other: 2 (1)
## property in {building society savings,real estate,unknown/none}: 1 (4/1)
##
## -----  Trial 1:  -----
##
## Decision tree:
##
## months_loan_duration <= 8:
## :...amount <= 3380: 1 (63.3/4.7)
## :   amount > 3380: 2 (11.8/4.7)
## months_loan_duration > 8:
## :...checking_balance in {< 0 DM,> 200 DM,1 - 200 DM}:
##     :...other_debtors = guarantor:
##     :   :...housing in {for free,own}: 1 (23.8/3.1)
##     :   :   housing = rent: 2 (5.9/1.6)
##     :   other_debtors in {co-applicant,none}:
##     :   :...installment_rate <= 2:
##     :       :...savings_balance in {> 1000 DM,501 - 1000 DM,
##     :       :   :                   unknown}: 1 (29.7/4.7)
##     :       :   savings_balance = 101 - 500 DM:
##     :       :   :...installment_plan = bank: 1 (4.3)
##     :       :   :   installment_plan in {none,stores}: 2 (17.2/6.2)
##     :       :   savings_balance = < 100 DM:
##     :       :   :...purpose in {car (new),car (used),domestic appliances,
##     :       :   :               retraining}: 1 (39.1/9.4)
##     :       :       purpose in {education,others,radio/tv,
##     :       :   :               repairs}: 2 (32.9/12.1)
##     :       :       purpose = business:
```

```
##      :         :            :...residence_history <= 1: 1 (6.7/0.8)
##      :         :            :  residence_history > 1: 2 (8.6/2.3)
##      :         :         purpose = furniture:
##      :         :         :...installment_rate <= 1: 1 (11.3/3.1)
##      :         :             installment_rate > 1:
##      :         :             :...months_loan_duration <= 16: 1 (4.7/0.8)
##      :         :                 months_loan_duration > 16: 2 (20.8/4.7)
##      :         installment_rate > 2:
##      :         :...residence_history <= 1: 1 (35.6/10.6)
##      :             residence_history > 1:
##      :             :...credit_history = fully repaid: 2 (12.1)
##      :                 credit_history in {critical,delayed,fully repaid this bank,
##      :                 :                  repaid}:
##      :                 :...purpose in {domestic appliances,education,
##      :                 :             others}: 2 (19.6/4.7)
##      :                     purpose in {repairs,retraining}: 1 (5.5/2.3)
##      :                     purpose = business:
##      :                     :...age <= 52: 1 (14.1/3.9)
##      :                     :   age > 52: 2 (4.3)
##      :                     purpose = car (used):
##      :                     :...housing = own: 1 (9)
##      :                     :   housing in {for free,rent}:
##      :                     :   :...installment_plan = bank: 1 (2.3)
##      :                     :       installment_plan in {none,stores}: 2 (12.5/2.3)
##      :                     purpose = radio/tv:
##      :                     :...employment_length in {0 - 1 yrs,1 - 4 yrs,
##      :                     :                     unemployed}: 2 (45.8/10.2)
##      :                     :   employment_length in {> 7 yrs,4 - 7 yrs}:
##      :                     :   :...months_loan_duration <= 39: 1 (16.4/1.6)
##      :                     :       months_loan_duration > 39: 2 (2.3)
##      :                     purpose = car (new):
##      :                     :...installment_plan in {bank,stores}: 2 (16.5/0.8)
##      :                     :   installment_plan = none:
##      :                     :   :...checking_balance in {< 0 DM,
##      :                     :   :                      > 200 DM}: 2 (35.2/7)
##      :                     :       checking_balance = 1 - 200 DM:
##      :                     :       :...residence_history <= 2: 2 (9/1.6)
##      :                     :           residence_history > 2: 1 (14.9/2.3)
##      :                     purpose = furniture:
##      :                     :...installment_plan = bank: 2 (3.1/0.8)
##      :                         installment_plan = stores: 1 (3.1)
##      :                         installment_plan = none: [S1]
##      checking_balance = unknown:
##      :...installment_plan in {bank,stores}:
##          :...employment_length in {1 - 4 yrs,unemployed}: 2 (37.3/7)
##          :   employment_length in {> 7 yrs,0 - 1 yrs,4 - 7 yrs}:
##          :   :...installment_plan = stores: 1 (7)
##          :       installment_plan = bank:
##          :       :...other_debtors = guarantor: 2 (0)
##          :           other_debtors = co-applicant: 1 (0.8)
##          :           other_debtors = none:
##          :           :...age <= 43: 2 (20/6.2)
##          :               age > 43: 1 (6.2)
##          installment_plan = none:
```

```
##           :...other_debtors = co-applicant: 2 (14.5/6.2)
##              other_debtors = guarantor: 1 (5.9/2.8)
##              other_debtors = none:
##              :...credit_history = delayed:
##                  :...residence_history <= 1: 2 (5.5)
##                  :    residence_history > 1:
##                  :    :...installment_rate <= 3: 1 (9.4)
##                  :        installment_rate > 3:
##                  :        :...property in {building society savings,other,
##                  :        :             unknown/none}: 2 (14.1/3.1)
##                  :            property = real estate: 1 (2.3)
##                  credit_history in {critical,fully repaid,
##                  :                  fully repaid this bank,repaid}:
##                  :...purpose in {car (new),car (used),domestic appliances,
##                     :           others,retraining}: 1 (68.8)
##                     purpose in {business,education,furniture,radio/tv,repairs}:
##                     :...personal_status in {divorced male,
##                         :                   married male}: 1 (10.9)
##                         personal_status = single male:
##                         :...age <= 23: 2 (3.5/0.8)
##                         :   age > 23: 1 (64.1/5.5)
##                         personal_status = female:
##                         :...employment_length in {> 7 yrs,
##                             :                     4 - 7 yrs}: 1 (10.2)
##                             employment_length in {0 - 1 yrs,1 - 4 yrs,
##                             :                     unemployed}:
##                             :...amount > 3249: 2 (11)
##                                 amount <= 3249:
##                                 :...installment_rate <= 3: 1 (5.5)
##                                     installment_rate > 3:
##                                     :...purpose in {education,furniture,
##                                         :           repairs}: 2 (12.2/3.9)
##                                         purpose in {business,
##                                                     radio/tv}: 1 (8.6)
##
## SubTree [S1]
##
## credit_history in {critical,delayed,fully repaid this bank}: 2 (14.1/5.5)
## credit_history = repaid:
## :...amount <= 4657: 1 (24.3/6.2)
##     amount > 4657: 2 (2.3)
##
## -----  Trial 2:  -----
##
## Decision tree:
##
## checking_balance = unknown:
## :...installment_plan in {bank,stores}:
## :    :...other_debtors in {co-applicant,guarantor}: 1 (2.8)
## :    :    other_debtors = none:
## :    :    :...employment_length = unemployed: 2 (6.6)
## :    :        employment_length in {> 7 yrs,0 - 1 yrs,1 - 4 yrs,4 - 7 yrs}:
## :    :        :...residence_history <= 1: 1 (6)
## :    :            residence_history > 1:
```

```
## :   :                  :...age > 44: 1 (7.8)
## :   :                  age <= 44:
## :   :                  :...purpose in {domestic appliances,others,repairs,
## :   :                  :          retraining}: 2 (0)
## :   :                  purpose in {business,car (new),education}:
## :   :                  :...savings_balance in {< 100 DM,101 - 500 DM,
## :   :                  :   :                   501 - 1000 DM,
## :   :                  :   :                   unknown}: 2 (21.4/1.6)
## :   :                  :   savings_balance = > 1000 DM: 1 (2.2)
## :   :                  purpose in {car (used),furniture,radio/tv}:
## :   :                  :...housing in {for free,own}: 1 (24.7/4.4)
## :   :                     housing = rent: 2 (5/0.6)
## :   installment_plan = none:
## :   :...credit_history in {critical,fully repaid,
## :       :                  fully repaid this bank}: 1 (88.8/4.4)
## :       credit_history in {delayed,repaid}:
## :       :...existing_credits > 1:
## :           :...residence_history <= 1: 2 (4.4)
## :           :   residence_history > 1:
## :           :   :...savings_balance in {501 - 1000 DM,unknown}: 1 (6.9)
## :           :       savings_balance in {< 100 DM,> 1000 DM,101 - 500 DM}:
## :           :       :...existing_credits > 2: 2 (3.6)
## :           :           existing_credits <= 2:
## :           :           :...property in {building society savings,
## :           :           :              real estate}: 1 (6.3)
## :           :              property in {other,unknown/none}: 2 (22.8/8.2)
## :           existing_credits <= 1:
## :           :...installment_rate <= 3: 1 (55.5/4.4)
## :               installment_rate > 3:
## :               :...credit_history = delayed: 2 (5/0.6)
## :                   credit_history = repaid:
## :                   :...other_debtors = guarantor: 2 (3.6)
## :                       other_debtors in {co-applicant,none}:
## :                       :...savings_balance in {> 1000 DM,101 - 500 DM,
## :                           :                   unknown}: 1 (18.2)
## :                           savings_balance in {< 100 DM,501 - 1000 DM}:
## :                           :...age <= 23: 2 (4.4)
## :                               age > 23:
## :                               :...purpose in {business,car (new),car (used),
## :                                   :           domestic appliances,education,
## :                                   :           others,radio/tv,repairs,
## :                                   :           retraining}: 1 (12.9)
## :                                   purpose = furniture: 2 (11/4.4)
## checking_balance in {< 0 DM,> 200 DM,1 - 200 DM}:
## :...other_debtors = guarantor:
##     :...months_loan_duration <= 15: 1 (12.5)
##     :   months_loan_duration > 15:
##     :   :...age <= 44: 2 (15.8/6)
##     :       age > 44: 1 (5)
##     other_debtors = co-applicant:
##     :...savings_balance in {> 1000 DM,101 - 500 DM,501 - 1000 DM}: 2 (2.8)
##     :   savings_balance = unknown: 1 (3.5)
##     :   savings_balance = < 100 DM:
##     :   :...amount <= 2012: 1 (6)
```

```
##      :          amount > 2012:
##      :          :...employment_length in {> 7 yrs,0 - 1 yrs,1 - 4 yrs,
##      :          :                    4 - 7 yrs}: 2 (17.7/1.3)
##      :          employment_length = unemployed: 1 (2.2)
##      other_debtors = none:
##      :...installment_rate > 2:
##          :...credit_history in {fully repaid,
##          :   :                  fully repaid this bank}: 2 (30.8/7.5)
##          :   credit_history = delayed:
##          :   :...savings_balance in {< 100 DM,> 1000 DM,101 - 500 DM,
##          :   :   :                   501 - 1000 DM}: 2 (18.6/4.1)
##          :   :   savings_balance = unknown: 1 (4.7)
##          :   credit_history = critical:
##          :   :...purpose in {business,car (used),domestic appliances,others,
##          :   :   :           repairs,retraining}: 1 (15.7/2.8)
##          :   :   purpose = education: 2 (3.5)
##          :   :   purpose = furniture:
##          :   :   :...age <= 53: 1 (13.6/2.2)
##          :   :   :   age > 53: 2 (2.2)
##          :   :   purpose = radio/tv:
##          :   :   :...housing = for free: 2 (2.2)
##          :   :   :   housing in {own,rent}: 1 (12.9/4.1)
##          :   :   purpose = car (new):
##          :   :   :...months_loan_duration <= 11: 1 (4.1)
##          :   :       months_loan_duration > 11:
##          :   :       :...amount <= 1659: 2 (12.6/1.6)
##          :   :           amount > 1659: 1 (9.5/2.8)
##          :   credit_history = repaid:
##          :   :...personal_status = divorced male: 1 (6.9/2.8)
##          :       personal_status = married male:
##          :       :...age <= 21: 2 (3.2)
##          :       :   age > 21: 1 (13.6/1.9)
##          :       personal_status = female:
##          :       :...age > 54: 1 (7.9)
##          :       :   age <= 54:
##          :       :   :...checking_balance in {< 0 DM,1 - 200 DM}: 2 (50.4/10.3)
##          :       :       checking_balance = > 200 DM: 1 (7.3/2.2)
##          :       personal_status = single male:
##          :       :...savings_balance in {> 1000 DM,101 - 500 DM,
##          :       :                       unknown}: 1 (21.1/5.7)
##          :           savings_balance = 501 - 1000 DM: 2 (2.2)
##          :           savings_balance = < 100 DM:
##          :           :...age > 32: 2 (30/5.3)
##          :               age <= 32:
##          :               :...property in {building society savings,
##          :               :               real estate}: 1 (19.5/1.9)
##          :               property in {other,unknown/none}: 2 (18.7/8.2)
##      installment_rate <= 2:
##      :...personal_status = divorced male:
##          :...housing = own: 1 (14.5/5.7)
##          :   housing in {for free,rent}: 2 (6)
##          personal_status = married male:
##          :...existing_credits <= 1: 2 (15.8/6.9)
##          :   existing_credits > 1: 1 (2.2)
```

```
##              personal_status = single male:
##              :...age <= 24: 2 (10.7/2.8)
##              :   age > 24:
##              :   :...installment_plan in {bank,stores}: 1 (16.4/1.3)
##              :       installment_plan = none:
##              :       :...amount <= 6419: 1 (44.5/6.3)
##              :           amount > 6419:
##              :           :...age <= 38: 1 (10.1/2.8)
##              :               age > 38: 2 (6.6)
##          personal_status = female:
##          :...employment_length = 4 - 7 yrs: 1 (6.3)
##              employment_length in {> 7 yrs,0 - 1 yrs,1 - 4 yrs,unemployed}:
##              :...savings_balance in {> 1000 DM,501 - 1000 DM,
##              :                       unknown}: 1 (11.6/3.2)
##              savings_balance = 101 - 500 DM: 2 (6.6/0.6)
##              savings_balance = < 100 DM:
##              :...residence_history <= 1: 1 (9.5/1.6)
##                  residence_history > 1:
##                  :...property = real estate: 2 (5)
##                      property in {building society savings,other,
##                      :              unknown/none}:
##                      :...checking_balance = > 200 DM: 1 (5.1)
##                          checking_balance in {< 0 DM,1 - 200 DM}:
##                          :...residence_history <= 3: 2 (8.8/0.6)
##                              residence_history > 3:
##                              :...existing_credits <= 2: 1 (21.5/8.2)
##                                  existing_credits > 2: 2 (2.2)
##
## -----  Trial 3:  -----
##
## Decision tree:
##
## checking_balance = unknown:
## :...installment_plan = bank:
## :   :...housing = for free: 1 (7.7/1.8)
## :   :   housing = rent: 2 (5.8/0.5)
## :   :   housing = own:
## :   :   :...savings_balance in {> 1000 DM,101 - 500 DM}: 1 (3.5)
## :   :       savings_balance in {501 - 1000 DM,unknown}: 2 (16.6/4.8)
## :   :       savings_balance = < 100 DM:
## :   :       :...purpose in {business,car (new),education}: 2 (8/1)
## :   :           purpose in {car (used),domestic appliances,furniture,others,
## :   :                       radio/tv,repairs,retraining}: 1 (8.6)
## :   installment_plan in {none,stores}:
## :   :...employment_length in {> 7 yrs,1 - 4 yrs,4 - 7 yrs}: 1 (190.9/29.3)
## :       employment_length in {0 - 1 yrs,unemployed}:
## :       :...other_debtors = guarantor: 1 (0)
## :           other_debtors = co-applicant: 2 (6.8)
## :           other_debtors = none:
## :           :...amount > 4594: 2 (12.9/1)
## :               amount <= 4594:
## :               :...purpose in {business,repairs}: 2 (3.5)
## :                   purpose in {car (new),car (used),domestic appliances,
## :                               education,furniture,others,radio/tv,
```

```
## :                                      retraining}: 1 (21.4)
## checking_balance in {< 0 DM,> 200 DM,1 - 200 DM}:
## :...other_debtors = guarantor: 1 (36.5/7.8)
##     other_debtors in {co-applicant,none}:
##     :...personal_status = divorced male: 2 (43.5/13.3)
##         personal_status = female:
##         :...residence_history <= 1:
##         :    :...purpose in {business,car (used),domestic appliances,education,
##         :    :    :              furniture,others,radio/tv,repairs,
##         :    :    :              retraining}: 1 (24/1.3)
##         :    :   purpose = car (new): 2 (11.7/4)
##         :   residence_history > 1:
##         :   :...installment_plan in {bank,stores}: 2 (18.8/2.3)
##         :       installment_plan = none:
##         :       :...age > 56: 1 (6.5)
##         :           age <= 56:
##         :           :...employment_length in {> 7 yrs,4 - 7 yrs,unemployed}:
##         :               :...age <= 28: 1 (17.7/1.8)
##         :               :   age > 28: 2 (21/7.2)
##         :               employment_length in {0 - 1 yrs,1 - 4 yrs}:
##         :               :...property = real estate: 2 (20.9/2.7)
##         :                   property = unknown/none: 1 (4.3/1.5)
##         :                   property in {building society savings,other}:
##         :                   :...checking_balance in {< 0 DM,
##         :                   :                        1 - 200 DM}: 2 (42.8/10.7)
##         :                   checking_balance = > 200 DM: 1 (5.3)
##         personal_status in {married male,single male}:
##         :...months_loan_duration <= 11:
##             :...property = real estate: 1 (27.6)
##             :   property in {building society savings,other,unknown/none}:
##             :   :...months_loan_duration > 9: 1 (5.3)
##             :       months_loan_duration <= 9:
##             :       :...purpose in {car (new),education}: 2 (8)
##             :           purpose in {business,car (used),domestic appliances,
##             :                       furniture,others,radio/tv,repairs,
##             :                       retraining}: 1 (11.2/1.8)
##             months_loan_duration > 11:
##             :...installment_plan = bank:
##                 :...amount <= 1393: 2 (13.2/1.7)
##                 :   amount > 1393: 1 (33.7/3.5)
##                 installment_plan = stores:
##                 :...amount <= 2255: 2 (9.7)
##                 :   amount > 2255: 1 (15/2.7)
##                 installment_plan = none:
##                 :...credit_history in {fully repaid,
##                     :                  fully repaid this bank}: 2 (15.4/4)
##                     credit_history = delayed:
##                     :...age > 47: 2 (3.2)
##                     :   age <= 47:
##                     :   :...residence_history <= 1: 2 (3.5/0.5)
##                     :       residence_history > 1: 1 (16.7/1)
##                     credit_history = critical:
##                     :...savings_balance in {> 1000 DM,101 - 500 DM,
##                     :   :                   unknown}: 1 (11.1/1.8)
```

```
##                          :      savings_balance = 501 - 1000 DM: 2 (3.5)
##                          :      savings_balance = < 100 DM:
##                          :      :...existing_credits > 2: 1 (3.3)
##                          :          existing_credits <= 2:
##                          :          :...checking_balance = < 0 DM: 2 (17.2/8.5)
##                          :              checking_balance = > 200 DM: 1 (1.8)
##                          :              checking_balance = 1 - 200 DM:
##                          :              :...residence_history <= 2: 2 (15.8/2.3)
##                          :                  residence_history > 2: 1 (5.8/1.8)
##                     credit_history = repaid:
##                     :...amount > 8086: 2 (10.2)
##                         amount <= 8086:
##                         :...age > 32:
##                             :...personal_status = married male: 1 (3.5)
##                             :   personal_status = single male: 2 (43.9/14.1)
##                             age <= 32:
##                             :...checking_balance = > 200 DM: 1 (12.2/1.8)
##                                 checking_balance = 1 - 200 DM:
##                                 :...purpose in {business,car (new),car (used),
##                                 :   :             domestic appliances,education,
##                                 :   :             furniture,others,
##                                 :   :             retraining}: 1 (21.4/3.3)
##                                 :   purpose in {radio/tv,repairs}: 2 (12.2/4.7)
##                                 checking_balance = < 0 DM:
##                                 :...housing = for free: 1 (4.9/0.5)
##                                     housing = rent: 2 (2.3/0.5)
##                                     housing = own:
##                                     :...residence_history <= 1: 2 (4.6/0.5)
##                                         residence_history > 1:
##                                         :...amount <= 4796: 1 (20.9/4.7)
##                                             amount > 4796: 2 (4.7)
##
## -----  Trial 4:  -----
##
## Decision tree:
##
## months_loan_duration <= 15:
## :...housing in {own,rent}: 1 (316.9/86)
## :   housing = for free:
## :   :...employment_length in {> 7 yrs,0 - 1 yrs,1 - 4 yrs,
## :   :                         4 - 7 yrs}: 2 (20.1/5.4)
## :       employment_length = unemployed: 1 (4.1)
## months_loan_duration > 15:
## :...savings_balance in {> 1000 DM,unknown}:
##     :...checking_balance = < 0 DM:
##     :   :...employment_length in {> 7 yrs,1 - 4 yrs,unemployed}: 2 (13.3/1.6)
##     :   :   employment_length in {0 - 1 yrs,4 - 7 yrs}: 1 (8.2/0.8)
##     :   checking_balance in {> 200 DM,1 - 200 DM,unknown}:
##     :   :...existing_credits <= 2: 1 (72.5/8.4)
##     :       existing_credits > 2: 2 (4.3/0.4)
##     savings_balance in {< 100 DM,101 - 500 DM,501 - 1000 DM}:
##     :...purpose in {domestic appliances,repairs}: 2 (9.9/4.3)
##         purpose in {others,retraining}: 1 (10.7/3.6)
##         purpose = car (used):
```

```
##            :...amount <= 8133: 1 (33/4.6)
##            :    amount > 8133: 2 (11.8/2.8)
##        purpose = business:
##        :...savings_balance in {101 - 500 DM,501 - 1000 DM}: 1 (13.8/2.2)
##        :    savings_balance = < 100 DM:
##        :    :...residence_history <= 1: 1 (12.9/2.4)
##        :        residence_history > 1: 2 (34.5/7.7)
##        purpose = education:
##        :...months_loan_duration <= 22: 2 (7.1)
##        :    months_loan_duration > 22:
##        :    :...installment_plan in {bank,none}: 1 (14.2/4.6)
##        :        installment_plan = stores: 2 (4.3)
##        purpose = radio/tv:
##        :...months_loan_duration > 36: 2 (13.7/1.8)
##        :    months_loan_duration <= 36:
##        :    :...credit_history in {delayed,fully repaid,
##        :    :                      fully repaid this bank}: 2 (14.2/4.2)
##        :        credit_history = critical:
##        :        :...employment_length in {> 7 yrs,4 - 7 yrs,
##        :        :    :                    unemployed}: 1 (12.4)
##        :        :    employment_length in {0 - 1 yrs,1 - 4 yrs}: 2 (7.6/2.2)
##        :        credit_history = repaid:
##        :        :...existing_credits > 1: 2 (7.7)
##        :            existing_credits <= 1:
##        :            :...other_debtors = co-applicant: 2 (5.6)
##        :                other_debtors in {guarantor,none}: 1 (52.9/9.3)
##        purpose = car (new):
##        :...installment_rate <= 1: 1 (10/1)
##        :    installment_rate > 1:
##        :    :...installment_plan in {bank,stores}: 2 (24.9/3.2)
##        :        installment_plan = none:
##        :        :...months_loan_duration <= 22: 1 (13.2/0.8)
##        :            months_loan_duration > 22:
##        :            :...checking_balance in {< 0 DM,> 200 DM}: 2 (10.1)
##        :                checking_balance in {1 - 200 DM,unknown}:
##        :                :...age <= 29: 2 (13.8/1.8)
##        :                    age > 29: 1 (18.4/4.7)
##        purpose = furniture:
##        :...installment_plan = stores: 1 (5.6)
##            installment_plan in {bank,none}:
##            :...other_debtors = guarantor: 1 (5.5)
##                other_debtors in {co-applicant,none}:
##                :...property in {other,real estate}: 2 (50/11.8)
##                    property in {building society savings,unknown/none}:
##                    :...amount > 6614: 2 (6.8)
##                        amount <= 6614: [S1]
##
## SubTree [S1]
##
## credit_history in {critical,delayed,repaid}: 1 (31.7/7.5)
## credit_history in {fully repaid,fully repaid this bank}: 2 (4.1)
##
## -----  Trial 5:  -----
##
```

```
## Decision tree:
##
## checking_balance in {> 200 DM,unknown}:
## :...employment_length in {> 7 yrs,4 - 7 yrs}:
## :    :...amount > 3632: 1 (33.5)
## :    :    amount <= 3632:
## :    :    :...credit_history = delayed: 2 (14.3/5.1)
## :    :        credit_history in {fully repaid,
## :    :        :                  fully repaid this bank}: 1 (5.8)
## :    :        credit_history = critical:
## :    :        :...residence_history > 3: 1 (14.2)
## :    :        :   residence_history <= 3:
## :    :        :   :...checking_balance = > 200 DM: 2 (4.6/0.3)
## :    :        :       checking_balance = unknown: 1 (15.3/4.5)
## :    :        credit_history = repaid:
## :    :        :...property in {building society savings,real estate}: 1 (14.6)
## :    :            property in {other,unknown/none}:
## :    :            :...existing_credits > 1: 2 (7.1/1.8)
## :    :                existing_credits <= 1:
## :    :                :...amount <= 1501: 2 (13.2/5.3)
## :    :                    amount > 1501: 1 (18.4)
## :    employment_length in {0 - 1 yrs,1 - 4 yrs,unemployed}:
## :    :...other_debtors in {co-applicant,guarantor}: 2 (17.1/4.9)
## :        other_debtors = none:
## :        :...amount > 3913:
## :            :...installment_plan = bank: 2 (14.7/2.6)
## :            :   installment_plan = stores: 1 (5.1/2.3)
## :            :   installment_plan = none:
## :            :   :...purpose in {domestic appliances,others,repairs,
## :            :   :                retraining}: 2 (0)
## :            :       purpose in {car (new),car (used),education}: 1 (7.5)
## :            :       purpose in {business,furniture,radio/tv}:
## :            :       :...property in {building society savings,other,
## :            :       :                unknown/none}: 2 (23.2/3.3)
## :            :           property = real estate: 1 (3.4)
## :            amount <= 3913:
## :            :...installment_rate <= 1: 1 (12)
## :                installment_rate > 1:
## :                :...purpose in {business,education}: 2 (17.3/6)
## :                    purpose in {car (new),car (used),domestic appliances,
## :                    :           furniture,others,repairs,
## :                    :           retraining}: 1 (53.2/12.3)
## :                    purpose = radio/tv:
## :                    :...checking_balance = unknown: 1 (17.2)
## :                        checking_balance = > 200 DM:
## :                        :...months_loan_duration <= 18: 2 (13.2/2)
## :                            months_loan_duration > 18: 1 (3.4)
## checking_balance in {< 0 DM,1 - 200 DM}:
## :...purpose in {domestic appliances,repairs,retraining}: 1 (31.8/10.9)
##     purpose = others: 2 (11.9/5.8)
##     purpose = car (used):
##     :...installment_plan in {bank,none}: 1 (43.5/15.2)
##     :   installment_plan = stores: 2 (3.3)
##     purpose = education:
```

```
##       :...age > 57: 1 (2.7)
##       :   age <= 57:
##       :   :...employment_length in {> 7 yrs,0 - 1 yrs,1 - 4 yrs,
##       :   :                            unemployed}: 2 (25.2/3)
##       :       employment_length = 4 - 7 yrs: 1 (5.3/1.1)
##       purpose = business:
##       :...months_loan_duration <= 18: 1 (15.7)
##       :   months_loan_duration > 18:
##       :   :...personal_status = divorced male: 2 (5)
##       :       personal_status = married male: 1 (2.9)
##       :       personal_status in {female,single male}:
##       :       :...savings_balance in {> 1000 DM,501 - 1000 DM}: 2 (0)
##       :           savings_balance in {101 - 500 DM,unknown}: 1 (10/2.3)
##       :           savings_balance = < 100 DM:
##       :           :...credit_history = critical: 1 (3.2)
##       :               credit_history in {delayed,fully repaid,
##       :                                   fully repaid this bank,
##       :                                   repaid}: 2 (17.3/2.3)
##       purpose = car (new):
##       :...savings_balance in {> 1000 DM,501 - 1000 DM}: 1 (7.5)
##       :   savings_balance in {< 100 DM,101 - 500 DM,unknown}:
##       :   :...age <= 29: 2 (54.5/8.7)
##       :       age > 29:
##       :       :...employment_length = > 7 yrs:
##       :           :...amount <= 629: 1 (3)
##       :           :   amount > 629: 2 (29/3.7)
##       :           employment_length in {0 - 1 yrs,1 - 4 yrs,4 - 7 yrs,unemployed}:
##       :           :...amount > 1459: 1 (32.9/3.9)
##       :               amount <= 1459:
##       :               :...other_debtors = guarantor: 2 (0)
##       :                   other_debtors = co-applicant: 1 (0.8)
##       :                   other_debtors = none:
##       :                   :...amount <= 674: 1 (2.4)
##       :                       amount > 674: 2 (17.2/3)
##       purpose = radio/tv:
##       :...months_loan_duration <= 11:
##       :   :...age <= 22: 2 (2.3)
##       :   :   age > 22: 1 (16.3)
##       :   months_loan_duration > 11:
##       :   :...credit_history in {critical,fully repaid,
##       :   :                       fully repaid this bank}: 2 (22.1/7.5)
##       :       credit_history = delayed: 1 (9.3/3)
##       :       credit_history = repaid:
##       :       :...amount > 5324: 2 (5.7)
##       :           amount <= 5324:
##       :           :...other_debtors = co-applicant: 2 (1.2)
##       :               other_debtors = guarantor: 1 (6.1)
##       :               other_debtors = none:
##       :               :...amount > 3190: 1 (10.1/0.3)
##       :                   amount <= 3190:
##       :                   :...property in {building society savings,real estate,
##       :                       :               unknown/none}: 2 (22/3.9)
##       :                       property = other:
##       :                       :...age > 29: 2 (7.3/1.2)
```

```
##     :                                  age <= 29:
##     :                                  :...amount <= 3029: 1 (13.7/1.5)
##     :                                      amount > 3029: 2 (2.1)
##     purpose = furniture:
##     :...other_debtors = guarantor: 1 (5.2)
##         other_debtors in {co-applicant,none}:
##         :...installment_plan = stores: 1 (4.5)
##             installment_plan in {bank,none}:
##             :...savings_balance = > 1000 DM: 1 (5.4)
##                 savings_balance in {101 - 500 DM,501 - 1000 DM}: 2 (6.8/0.3)
##                 savings_balance in {< 100 DM,unknown}:
##                 :...residence_history <= 1: 1 (14.2/3)
##                     residence_history > 1:
##                     :...property in {real estate,unknown/none}: 2 (25.5/6.8)
##                         property = other:
##                         :...existing_credits <= 1: 2 (24.9/6.9)
##                         :   existing_credits > 1: 1 (5.7)
##                         property = building society savings:
##                         :...amount <= 1768: 1 (9.6)
##                             amount > 1768:
##                             :...other_debtors = co-applicant: 1 (1.1)
##                                 other_debtors = none:
##                                 :...housing in {for free,rent}: 2 (4.6)
##                                     housing = own:
##                                     :...months_loan_duration <= 13: 2 (6.7)
##                                         months_loan_duration > 13: 1 (14.4/5.5)
##
## -----  Trial 6:  -----
##
## Decision tree:
##
## checking_balance in {> 200 DM,unknown}:
## :...installment_plan = stores:
## :   :...installment_rate <= 3: 1 (6.6)
## :   :   installment_rate > 3: 2 (12.1/4.5)
## :   installment_plan = bank:
## :   :...property = real estate: 2 (9.8/1.6)
## :   :   property = unknown/none: 1 (14.4/2.7)
## :   :   property = building society savings:
## :   :   :...credit_history in {critical,fully repaid}: 2 (11.9/1.7)
## :   :   :   credit_history in {delayed,fully repaid this bank,
## :   :   :                      repaid}: 1 (6.2)
## :   :   property = other:
## :   :   :...housing in {for free,own}: 1 (15.9/4.3)
## :   :       housing = rent: 2 (1.8)
## :   installment_plan = none:
## :   :...purpose in {car (used),domestic appliances,others,radio/tv,
## :   :               retraining}: 1 (99.3/22.4)
## :       purpose = repairs: 2 (7.1/3.2)
## :       purpose = business:
## :       :...existing_credits <= 2: 1 (24.4/4.4)
## :       :   existing_credits > 2: 2 (2.5)
## :       purpose = education:
## :       :...months_loan_duration <= 16: 1 (11.3)
```

```
## :            :     months_loan_duration > 16: 2 (5.3/1.5)
## :         purpose = car (new):
## :         :...installment_rate <= 3: 1 (18.6/0.9)
## :         :   installment_rate > 3:
## :         :   :...other_debtors in {co-applicant,none}: 1 (21.4/4.5)
## :         :         other_debtors = guarantor: 2 (3.7)
## :         purpose = furniture:
## :         :...personal_status = divorced male: 1 (2.2)
## :             personal_status = married male: 2 (2.5/0.8)
## :             personal_status = female:
## :             :...checking_balance = > 200 DM: 1 (2.9)
## :             :   checking_balance = unknown: 2 (24.9/8.4)
## :             personal_status = single male:
## :             :...residence_history <= 1: 2 (3.1)
## :                 residence_history > 1: 1 (16.6)
## checking_balance in {< 0 DM,1 - 200 DM}:
## :...property in {building society savings,other,unknown/none}:
##     :...credit_history = fully repaid this bank:
##     :   :...other_debtors = co-applicant: 1 (3.7)
##     :   :   other_debtors in {guarantor,none}: 2 (31.8/9.3)
##     :   credit_history = fully repaid:
##     :   :...housing in {for free,rent}: 2 (13.6)
##     :   :   housing = own:
##     :   :   :...age <= 37: 1 (12/2.7)
##     :   :         age > 37: 2 (4.2)
##     :   credit_history = critical:
##     :   :...residence_history <= 1: 1 (5.5)
##     :   :   residence_history > 1:
##     :   :   :...months_loan_duration <= 8: 1 (8.8)
##     :   :         months_loan_duration > 8:
##     :   :         :...other_debtors in {co-applicant,guarantor}: 2 (10.7/3.4)
##     :   :             other_debtors = none:
##     :   :             :...months_loan_duration <= 27: 1 (43/14.4)
##     :   :                 months_loan_duration > 27: 2 (20.9/4.7)
##     :   credit_history = delayed:
##     :   :...checking_balance = < 0 DM: 2 (8.5/0.3)
##     :   :   checking_balance = 1 - 200 DM:
##     :   :   :...housing = rent: 1 (6.3)
##     :   :         housing in {for free,own}:
##     :   :         :...personal_status in {female,married male}: 2 (4.8)
##     :   :             personal_status in {divorced male,single male}:
##     :   :             :...residence_history <= 2: 1 (5.5)
##     :   :                 residence_history > 2:
##     :   :                 :...amount <= 2288: 2 (4.5)
##     :   :                     amount > 2288: 1 (13/3.6)
##     :   credit_history = repaid:
##     :   :...amount > 8086:
##     :       :...other_debtors = co-applicant: 1 (3.5/0.7)
##     :       :   other_debtors in {guarantor,none}: 2 (24.6/1.3)
##     :       amount <= 8086:
##     :       :...savings_balance = > 1000 DM: 1 (2.8)
##     :           savings_balance = 501 - 1000 DM: 2 (4.6/1.5)
##     :           savings_balance = 101 - 500 DM:
##     :           :...personal_status in {divorced male,female,
```

```
##     :                   :   :                          married male}: 2 (12.6)
##     :                   :   personal_status = single male: 1 (10.3/2.8)
##     :               savings_balance = unknown:
##     :               :...checking_balance = 1 - 200 DM: 1 (16.7/4.6)
##     :               :   checking_balance = < 0 DM:
##     :               :   :...age <= 37: 2 (13.4/2)
##     :               :       age > 37: 1 (8.8/3.5)
##     :               savings_balance = < 100 DM:
##     :               :...purpose in {business,car (used),others,
##     :               :               radio/tv}: 1 (47.7/17.8)
##     :                   purpose in {domestic appliances,education,repairs,
##     :                   :               retraining}: 2 (19.9/7.4)
##     :                   purpose = car (new):
##     :                   :...residence_history <= 3: 2 (18.6/4)
##     :                   :   residence_history > 3:
##     :                   :   :...installment_rate <= 2: 1 (7.5)
##     :                   :       installment_rate > 2: 2 (7.9/2.2)
##     :                   purpose = furniture:
##     :                   :...employment_length = 0 - 1 yrs: 1 (7.4)
##     :                       employment_length in {> 7 yrs,1 - 4 yrs,4 - 7 yrs,
##     :                       :                       unemployed}:
##     :                       :...other_debtors in {co-applicant,
##     :                       :               guarantor}: 1 (5.1/0.9)
##     :                           other_debtors = none:
##     :                           :...personal_status in {divorced male,
##     :                           :               female}: 1 (16.2/5.7)
##     :                               personal_status in {married male,
##     :                                           single male}: 2 (13.8/2.5)
##     property = real estate:
##     :...savings_balance in {> 1000 DM,101 - 500 DM,501 - 1000 DM,
##         :                   unknown}: 1 (32.3/4.7)
##         savings_balance = < 100 DM:
##         :...months_loan_duration <= 11: 1 (22.1/3.1)
##             months_loan_duration > 11:
##             :...installment_plan = stores: 2 (4.5)
##                 installment_plan in {bank,none}:
##                 :...age > 38:
##                     :...residence_history <= 1: 2 (2.3/0.3)
##                     :   residence_history > 1: 1 (22.4/1)
##                     age <= 38:
##                     :...existing_credits > 1: 2 (20.5/3.1)
##                         existing_credits <= 1:
##                         :...checking_balance = 1 - 200 DM: 1 (12.8/1.2)
##                             checking_balance = < 0 DM:
##                             :...age <= 26: 2 (8.9)
##                                 age > 26: 1 (11.8/5)
##
## -----  Trial 7:  -----
##
## Decision tree:
##
## checking_balance = unknown:
## :...installment_plan = bank:
## :   :...savings_balance in {< 100 DM,> 1000 DM,101 - 500 DM}: 1 (30.7/11.7)
```

```
## :    :    savings_balance in {501 - 1000 DM,unknown}: 2 (21.2/8.3)
## :    installment_plan in {none,stores}:
## :    :...credit_history in {critical,fully repaid,
## :    :                       fully repaid this bank}: 1 (62.5/7.7)
## :        credit_history = delayed:
## :        :...residence_history <= 1: 2 (4.1)
## :        :   residence_history > 1:
## :        :   :...installment_rate <= 3: 1 (15.4)
## :        :        installment_rate > 3:
## :        :        :...amount <= 2442: 1 (12.7/4.2)
## :        :             amount > 2442: 2 (7.1/0.7)
## :        credit_history = repaid:
## :        :...employment_length = unemployed: 2 (4.6/1.2)
## :            employment_length = > 7 yrs:
## :            :...savings_balance in {< 100 DM,> 1000 DM,501 - 1000 DM,
## :            :   :                      unknown}: 1 (15.1)
## :            :   savings_balance = 101 - 500 DM: 2 (4.7/1.3)
## :            employment_length = 0 - 1 yrs:
## :            :...other_debtors = co-applicant: 2 (2.8)
## :            :   other_debtors in {guarantor,none}: 1 (16.3/6.5)
## :            employment_length = 4 - 7 yrs:
## :            :...age <= 22: 2 (4.6/0.9)
## :            :   age > 22: 1 (17.1)
## :            employment_length = 1 - 4 yrs:
## :            :...property = real estate: 1 (14.5)
## :                property in {building society savings,other,unknown/none}:
## :                :...age <= 26: 1 (6.2)
## :                    age > 26: 2 (18.1/5.4)
## checking_balance in {< 0 DM,> 200 DM,1 - 200 DM}:
## :...other_debtors = guarantor:
##     :...months_loan_duration <= 36: 1 (28.3/4.7)
##     :   months_loan_duration > 36: 2 (4/0.7)
##     other_debtors in {co-applicant,none}:
##     :...employment_length in {4 - 7 yrs,unemployed}:
##         :...age > 56: 1 (11.5)
##         :   age <= 56:
##         :   :...amount <= 1845:
##         :   :   :...employment_length = unemployed: 2 (10.4/1.1)
##         :   :   :   employment_length = 4 - 7 yrs:
##         :   :   :   :...age <= 38: 2 (22.8/4.5)
##         :   :   :        age > 38: 1 (4.9)
##         :   :   amount > 1845:
##         :   :   :...housing in {for free,rent}: 1 (40.9/5.7)
##         :   :       housing = own:
##         :   :       :...credit_history in {critical,
##         :   :       :                       fully repaid this bank}: 1 (20.6/3.9)
##         :   :       credit_history in {delayed,fully repaid}: 2 (8.5/2.5)
##         :   :       credit_history = repaid:
##         :   :       :...property in {building society savings,
##         :   :       :                   unknown/none}: 2 (14.7/2.5)
##         :   :           property in {other,real estate}: 1 (20.8/6.5)
##         employment_length in {> 7 yrs,0 - 1 yrs,1 - 4 yrs}:
##         :...months_loan_duration > 30:
##             :...residence_history > 3: 2 (37.6/3.7)
```

```
##                    :    residence_history <= 3:
##                    :    :...personal_status in {divorced male,
##                    :    :                       married male}: 1 (6.7/0.9)
##                    :         personal_status in {female,single male}:
##                    :         :...housing = for free: 1 (2.6/0.7)
##                    :              housing = rent: 2 (5.2/2.3)
##                    :              housing = own:
##                    :              :...residence_history <= 1: 1 (6.7/1.2)
##                    :                   residence_history > 1: 2 (21.9/1.9)
##               months_loan_duration <= 30:
##               :...purpose = domestic appliances: 2 (2.6/0.9)
##                   purpose in {others,repairs,retraining}: 1 (23.6/8.5)
##                   purpose = education:
##                   :...residence_history <= 3: 2 (7)
##                   :   residence_history > 3: 1 (11/3.1)
##                   purpose = business:
##                   :...housing in {for free,rent}: 2 (4.3)
##                   :   housing = own:
##                   :   :...age <= 37: 1 (18.9/3.4)
##                   :       age > 37: 2 (5/1.5)
##                   purpose = car (new):
##                   :...credit_history = delayed: 1 (6.6/1)
##                   :   credit_history in {fully repaid,fully repaid this bank,
##                   :   :                  repaid}: 2 (56/16.1)
##                   :   credit_history = critical:
##                   :   :...other_debtors = co-applicant: 2 (2.8)
##                   :       other_debtors = none: 1 (23.1/6.2)
##                   purpose = car (used):
##                   :...credit_history = fully repaid: 2 (0)
##                   :   credit_history in {critical,delayed}: 1 (5.9)
##                   :   credit_history in {fully repaid this bank,repaid}:
##                   :   :...amount <= 3161: 1 (2.6)
##                   :       amount > 3161: 2 (14.5/1)
##                   purpose = radio/tv:
##                   :...employment_length = > 7 yrs:
##                   :   :...amount <= 932: 2 (3.8/0.4)
##                   :   :   amount > 932: 1 (16.8)
##                   :   employment_length in {0 - 1 yrs,1 - 4 yrs}:
##                   :   :...other_debtors = co-applicant: 1 (4.5/0.7)
##                   :       other_debtors = none:
##                   :       :...amount <= 3190: 2 (67.1/18.2)
##                   :           amount > 3190: 1 (7.1/0.7)
##                   purpose = furniture:
##                   :...installment_plan = stores: 1 (5)
##                       installment_plan in {bank,none}:
##                       :...savings_balance in {> 1000 DM,
##                           :                   101 - 500 DM}: 1 (5/0.9)
##                           savings_balance = 501 - 1000 DM: 2 (0.2)
##                           savings_balance = unknown:
##                           :...existing_credits <= 1: 2 (13.2/4.8)
##                           :   existing_credits > 1: 1 (2.3)
##                           savings_balance = < 100 DM: [S1]
##
## SubTree [S1]
```

```
##
## credit_history in {delayed,fully repaid,fully repaid this bank}: 2 (10.3/3.4)
## credit_history = critical:
## :...amount <= 1680: 1 (4.6)
## :    amount > 1680: 2 (11.4/1.6)
## credit_history = repaid:
## :...employment_length = 0 - 1 yrs: 1 (8.8/0.5)
##     employment_length in {> 7 yrs,1 - 4 yrs}:
##     :...personal_status = divorced male: 1 (4.2)
##         personal_status in {female,married male,single male}: 2 (26.1/9.6)
##
## -----  Trial 8:  -----
##
## Decision tree:
##
## months_loan_duration <= 7:
## :...existing_credits > 1: 1 (13.5)
## :    existing_credits <= 1:
## :    :...amount > 3380: 2 (8.3/1.6)
## :        amount <= 3380:
## :        :...purpose in {business,car (new),car (used),domestic appliances,
## :        :               furniture,others,radio/tv,repairs,
## :        :               retraining}: 1 (35.6/1.8)
## :            purpose = education: 2 (5.1/1)
## months_loan_duration > 7:
## :...checking_balance in {< 0 DM,1 - 200 DM}:
##     :...property = unknown/none:
##     :   :...installment_rate > 3: 2 (46.5/10)
##     :   :   installment_rate <= 3:
##     :   :   :...personal_status in {divorced male,female,
##     :   :   :                       married male}: 2 (16.3/5.5)
##     :   :       personal_status = single male:
##     :   :       :...installment_plan in {bank,stores}: 1 (8.5/0.7)
##     :   :           installment_plan = none:
##     :   :           :...age > 44: 2 (5.9)
##     :   :               age <= 44:
##     :   :               :...months_loan_duration <= 13: 2 (3.7)
##     :   :                   months_loan_duration > 13: 1 (11.3/1.4)
##     :   property = other:
##     :   :...amount <= 1386:
##     :   :   :...savings_balance in {> 1000 DM,501 - 1000 DM}: 1 (3.3)
##     :   :   :   savings_balance in {< 100 DM,101 - 500 DM,unknown}:
##     :   :   :   :...amount <= 458: 1 (2.2)
##     :   :   :       amount > 458: 2 (40.2/3.6)
##     :   :   amount > 1386:
##     :   :   :...installment_rate <= 1:
##     :   :       :...amount <= 8858: 1 (18.2/0.9)
##     :   :       :   amount > 8858: 2 (3.4)
##     :   :       installment_rate > 1:
##     :   :       :...savings_balance in {> 1000 DM,unknown}: 1 (15.1/2.5)
##     :   :           savings_balance = 501 - 1000 DM: 2 (2.8/0.8)
##     :   :           savings_balance = 101 - 500 DM:
##     :   :           :...personal_status in {female,married male}: 2 (7)
##     :   :               :   personal_status in {divorced male,single male}:
```

```
##      :    :                 :    :...age <= 40: 1 (14.5)
##      :    :                 :        age > 40: 2 (3.3)
##      :    :              savings_balance = < 100 DM:
##      :    :              :...purpose = retraining: 2 (0)
##      :    :                  purpose in {car (used),repairs}: 1 (9.1)
##      :    :                  purpose in {business,car (new),domestic appliances,
##      :    :                  :             education,furniture,others,radio/tv}:
##      :    :                  :...installment_plan = stores: 1 (7.2/1.4)
##      :    :                      installment_plan in {bank,none}:
##      :    :                      :...months_loan_duration <= 16: 1 (13.3/3.5)
##      :    :                          months_loan_duration > 16: 2 (52.6/11.5)
##      :    property = real estate:
##      :    :...months_loan_duration <= 11: 1 (19.8/1.8)
##      :    :   months_loan_duration > 11:
##      :    :   :...savings_balance in {> 1000 DM,101 - 500 DM}: 1 (7)
##      :    :        savings_balance in {< 100 DM,501 - 1000 DM,unknown}:
##      :    :        :...personal_status = divorced male: 2 (6.4/2.1)
##      :    :            personal_status = married male: 1 (18.3/6.2)
##      :    :            personal_status = female:
##      :    :            :...age > 38: 1 (6.5)
##      :    :            :   age <= 38:
##      :    :            :   :...installment_rate <= 1: 1 (3.1/0.4)
##      :    :            :       installment_rate > 1: 2 (18.3/1.8)
##      :    :            personal_status = single male:
##      :    :            :...savings_balance = 501 - 1000 DM: 2 (3.3/1.2)
##      :    :                savings_balance = unknown: 1 (4)
##      :    :                savings_balance = < 100 DM:
##      :    :                :...residence_history <= 1: 2 (3.9/0.6)
##      :    :                    residence_history > 1:
##      :    :                    :...existing_credits <= 1: 1 (12.7/2.1)
##      :    :                        existing_credits > 1: 2 (16.8/6.8)
##      :    property = building society savings:
##      :    :...installment_plan in {bank,stores}: 2 (19.8/6.1)
##      :        installment_plan = none:
##      :        :...other_debtors = guarantor: 1 (6.4)
##      :            other_debtors in {co-applicant,none}:
##      :            :...credit_history in {fully repaid,
##      :            :                fully repaid this bank}: 2 (4.9)
##      :                credit_history in {critical,delayed,repaid}:
##      :                :...savings_balance in {> 1000 DM,unknown}: 1 (14/5.1)
##      :                    savings_balance in {101 - 500 DM,
##      :                    :                501 - 1000 DM}: 2 (10.2/3.6)
##      :                    savings_balance = < 100 DM:
##      :                    :...amount > 7814: 2 (5.7)
##      :                        amount <= 7814:
##      :                        :...employment_length in {1 - 4 yrs,4 - 7 yrs,
##      :                        :                unemployed}: 1 (39.2/8.2)
##      :                            employment_length = > 7 yrs:
##      :                            :...age <= 31: 1 (5)
##      :                            :   age > 31: 2 (11/2.1)
##      :                            employment_length = 0 - 1 yrs:
##      :                            :...purpose in {business,car (new),car (used),
##      :                            :                domestic appliances,furniture,
##      :                            :                others,repairs,
```

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```
##     :                                      :          retraining}: 1 (10.6/1.8)
##     :                                 purpose in {education,
##     :                                         radio/tv}: 2 (5.6)
##     checking_balance in {> 200 DM,unknown}:
##     :...installment_plan = bank:
##         :...housing = rent: 2 (6.3)
##         :   housing in {for free,own}:
##         :   :...savings_balance in {> 1000 DM,101 - 500 DM,
##         :   :                       501 - 1000 DM}: 1 (14.4/4.3)
##         :       savings_balance = unknown:
##         :       :...property in {building society savings,real estate}: 2 (7.3)
##         :       :   property in {other,unknown/none}: 1 (7.6)
##         :       savings_balance = < 100 DM:
##         :       :...personal_status in {divorced male,
##         :       :                       married male}: 2 (0)
##         :           personal_status = female: 1 (2.5)
##         :           personal_status = single male:
##         :           :...other_debtors = guarantor: 2 (0)
##         :               other_debtors = co-applicant: 1 (1.2)
##         :               other_debtors = none:
##         :               :...age <= 44: 2 (16.8/4.5)
##         :                   age > 44: 1 (2.4)
##         installment_plan in {none,stores}:
##         :...purpose in {car (used),domestic appliances,others,
##         :               retraining}: 1 (21.7)
##           purpose in {business,car (new),education,furniture,radio/tv,
##         :               repairs}:
##         :...employment_length = unemployed: 2 (7.1/2.3)
##             employment_length = > 7 yrs:
##             :...credit_history in {critical,fully repaid,
##             :   :                  fully repaid this bank,
##             :   :                  repaid}: 1 (36.1/4.2)
##             :   credit_history = delayed: 2 (10.2/3.5)
##             employment_length = 0 - 1 yrs:
##             :...installment_plan = stores: 1 (2)
##             :   installment_plan = none:
##             :   :...property = building society savings: 1 (11.5/3.3)
##             :       property in {other,real estate,
##             :                    unknown/none}: 2 (21.1/6.4)
##             employment_length = 4 - 7 yrs:
##             :...existing_credits > 2: 2 (2.1)
##             :   existing_credits <= 2:
##             :   :...months_loan_duration <= 9: 2 (3)
##             :       months_loan_duration > 9: 1 (28.1/1.2)
##             employment_length = 1 - 4 yrs:
##             :...installment_plan = stores: 2 (9.3/3.2)
##                 installment_plan = none:
##                 :...age > 30: 1 (39.8/5.9)
##                     age <= 30:
##                     :...installment_rate <= 2: 1 (8.2)
##                         installment_rate > 2:
##                         :...age <= 25: 1 (5.7)
##                             age > 25:
##                             :...checking_balance = > 200 DM: 2 (5.9)
```

```
##                                          checking_balance = unknown: [S1]
##
## SubTree [S1]
##
## property in {building society savings,other}: 2 (17.6/4.5)
## property in {real estate,unknown/none}: 1 (12.9/3)
##
## -----  Trial 9:  -----
##
## Decision tree:
##
## checking_balance in {> 200 DM,unknown}:
## :...installment_plan = stores: 1 (22.4/6.5)
## :   installment_plan = bank:
## :   :...housing = rent: 2 (5.5/0.5)
## :   :   housing in {for free,own}:
## :   :   :...personal_status in {divorced male,female,
## :   :   :                       married male}: 1 (13.1/4.9)
## :   :         personal_status = single male:
## :   :         :...purpose in {business,car (new),education}: 2 (19.1/5.2)
## :   :              purpose in {car (used),domestic appliances,furniture,others,
## :   :                          radio/tv,repairs,retraining}: 1 (23/3.2)
## :   installment_plan = none:
## :   :...purpose in {car (new),car (used),domestic appliances,others,repairs,
## :   :              retraining}: 1 (76.9/12.2)
## :       purpose = education:
## :       :...property in {building society savings,other,
## :       :   :           unknown/none}: 1 (11.4/0.5)
## :       :   property = real estate: 2 (4.4/0.3)
## :       purpose = business:
## :       :...existing_credits > 2: 2 (2.7)
## :       :   existing_credits <= 2:
## :       :   :...credit_history in {critical,fully repaid,
## :       :   :                      fully repaid this bank,repaid}: 1 (8.5)
## :       :       credit_history = delayed: 2 (8.7/3.1)
## :       purpose = furniture:
## :       :...months_loan_duration > 30: 2 (7/1.6)
## :       :   months_loan_duration <= 30:
## :       :   :...residence_history <= 1: 2 (9.7/2.2)
## :       :       residence_history > 1:
## :       :       :...residence_history <= 3: 1 (20.7/0.9)
## :       :           residence_history > 3:
## :       :           :...months_loan_duration <= 7: 2 (2.4)
## :       :               months_loan_duration > 7: 1 (13.8/2.3)
## :       purpose = radio/tv:
## :       :...personal_status in {divorced male,married male}: 1 (9.2)
## :           personal_status in {female,single male}:
## :           :...checking_balance = > 200 DM:
## :               :...months_loan_duration <= 9: 2 (4.7)
## :               :   months_loan_duration > 9:
## :               :   :...residence_history <= 3: 1 (14.8/4.1)
## :               :       residence_history > 3: 2 (3.4/0.1)
## :               checking_balance = unknown:
## :               :...credit_history in {critical,fully repaid,
```

```
## :                        :                        fully repaid this bank}: 1 (10.6)
## :                  credit_history in {delayed,repaid}:
## :                     :...existing_credits > 1: 2 (13.3/5)
## :                          existing_credits <= 1:
## :                          :...employment_length in {> 7 yrs,0 - 1 yrs,
## :                          :                        1 - 4 yrs}: 1 (17.2)
## :                              employment_length in {4 - 7 yrs,
## :                                                    unemployed}: 2 (6.3/2.3)
## checking_balance in {< 0 DM,1 - 200 DM}:
## :...credit_history = fully repaid this bank:
##     :...months_loan_duration <= 9: 2 (6)
##     :   months_loan_duration > 9: 1 (27.7/10.4)
##     credit_history = delayed:
##     :...savings_balance = > 1000 DM: 2 (2.3)
##     :   savings_balance in {101 - 500 DM,501 - 1000 DM,unknown}: 1 (24.7/2.8)
##     :   savings_balance = < 100 DM:
##     :   :...installment_rate <= 2: 1 (11/2.4)
##     :        installment_rate > 2:
##     :        :...months_loan_duration <= 15: 1 (5.8/2)
##     :            months_loan_duration > 15: 2 (12.2)
##     credit_history = fully repaid:
##     :...housing in {for free,rent}: 2 (12.4)
##     :   housing = own:
##     :   :...age > 34: 2 (4.2)
##     :        age <= 34:
##     :        :...amount > 11054: 2 (2.3)
##     :            amount <= 11054:
##     :            :...amount <= 2687: 2 (3.2/0.9)
##     :                amount > 2687: 1 (12)
##     credit_history = critical:
##     :...residence_history <= 1: 1 (7.2)
##     :   residence_history > 1:
##     :   :...savings_balance in {> 1000 DM,101 - 500 DM,501 - 1000 DM,
##     :   :                       unknown}: 1 (22.6/5.4)
##     :        savings_balance = < 100 DM:
##     :        :...age > 61: 1 (8)
##     :            age <= 61:
##     :            :...months_loan_duration > 36: 2 (4.8)
##     :                months_loan_duration <= 36:
##     :                :...age > 48: 2 (10.8/3.3)
##     :                    age <= 48:
##     :                    :...age <= 35:
##     :                        :...age <= 27: 1 (16/4.7)
##     :                        :   age > 27: 2 (20/5.3)
##     :                        age > 35:
##     :                        :...housing in {for free,own}: 1 (27.2/4.5)
##     :                            housing = rent: 2 (5.5/1.7)
##     credit_history = repaid:
##     :...savings_balance in {> 1000 DM,501 - 1000 DM}: 1 (17.4/3.3)
##         savings_balance in {< 100 DM,101 - 500 DM,unknown}:
##         :...other_debtors = guarantor: 1 (14.3/3.6)
##             other_debtors = co-applicant:
##             :...housing in {for free,rent}: 2 (3.3)
##             :   housing = own: 1 (11.9/3.7)
```

```
##              other_debtors = none:
##              :...amount > 8648: 2 (14/0.5)
##                  amount <= 8648:
##                  :...age <= 25: 2 (88.1/29.8)
##                      age > 25:
##                      :...installment_rate <= 2:
##                          :...installment_plan in {bank,stores}: 1 (5.2)
##                          :   installment_plan = none:
##                          :   :...amount <= 1386: 2 (5.8/1.3)
##                          :        amount > 1386: 1 (35.6/7.9)
##                          installment_rate > 2:
##                          :...months_loan_duration <= 11: 1 (12/0.6)
##                              months_loan_duration > 11:
##                              :...residence_history <= 1: 1 (23/6.2)
##                                  residence_history > 1: [S1]
##
## SubTree [S1]
##
## personal_status = divorced male: 2 (6.2/1.3)
## personal_status = married male: 1 (7.4/2.2)
## personal_status = female:
## :...age <= 54: 2 (16.1)
## :   age > 54: 1 (5)
## personal_status = single male:
## :...savings_balance = 101 - 500 DM: 1 (4.3)
##     savings_balance in {< 100 DM,unknown}:
##     :...installment_plan = bank: 1 (5.9/1)
##         installment_plan = stores: 2 (4.5)
##         installment_plan = none:
##         :...employment_length = unemployed: 1 (4)
##             employment_length in {> 7 yrs,0 - 1 yrs,1 - 4 yrs,4 - 7 yrs}:
##             :...age <= 28: 1 (7.5/1.2)
##                 age > 28:
##                 :...existing_credits > 1: 1 (4.5/0.7)
##                     existing_credits <= 1:
##                     :...age <= 57: 2 (27.2/2.4)
##                         age > 57: 1 (2)
##
## -----  Trial 10:  -----
##
## Decision tree:
##
## checking_balance = unknown:
## :...installment_plan = none: 1 (182/45.7)
## :   installment_plan in {bank,stores}:
## :   :...employment_length in {0 - 1 yrs,4 - 7 yrs}: 1 (12.4/3.2)
## :       employment_length = unemployed: 2 (6.2/0.7)
## :       employment_length = > 7 yrs:
## :       :...age > 41: 1 (9.4)
## :       :   age <= 41:
## :       :   :...age <= 32: 1 (4.6)
## :       :        age > 32: 2 (10.5/1.1)
## :       employment_length = 1 - 4 yrs:
## :       :...residence_history <= 1: 1 (4.5)
```

```
## :              residence_history > 1:
## :              :...installment_rate <= 1: 1 (6.9/1.8)
## :                 installment_rate > 1:
## :                 :...purpose in {business,car (new),car (used),
## :                 :                domestic appliances,education,furniture,others,
## :                 :                repairs,retraining}: 2 (15.7/1.1)
## :                 purpose = radio/tv: 1 (3.5)
## checking_balance in {< 0 DM,> 200 DM,1 - 200 DM}:
## :...credit_history in {fully repaid,fully repaid this bank}:
##     :...housing = rent: 2 (14.6/1.2)
##     :   housing = for free:
##     :   :...other_debtors = co-applicant: 1 (2.5)
##     :   :   other_debtors in {guarantor,none}: 2 (13.2/1.3)
##     :   housing = own:
##     :   :...savings_balance in {> 1000 DM,501 - 1000 DM}: 1 (4.3)
##     :       savings_balance in {101 - 500 DM,unknown}: 2 (10.1/3.5)
##     :       savings_balance = < 100 DM:
##     :       :...credit_history = fully repaid this bank: 2 (11.1/2.6)
##     :           credit_history = fully repaid:
##     :           :...age <= 33: 1 (14.1/2.7)
##     :               age > 33: 2 (5.3)
##     credit_history in {critical,delayed,repaid}:
##     :...other_debtors = co-applicant:
##         :...amount <= 2022: 1 (4.2)
##         :   amount > 2022:
##         :   :...employment_length in {> 7 yrs,0 - 1 yrs,1 - 4 yrs,
##         :   :                         4 - 7 yrs}: 2 (22/4)
##         :       employment_length = unemployed: 1 (3.7)
##         other_debtors = guarantor:
##         :...property = other: 1 (0)
##         :   property = unknown/none: 2 (2.6/0.1)
##         :   property in {building society savings,real estate}:
##         :   :...months_loan_duration <= 45: 1 (19.3/2.9)
##         :       months_loan_duration > 45: 2 (3)
##         other_debtors = none:
##         :...purpose in {business,domestic appliances,others}: 1 (45/12.6)
##             purpose = retraining: 2 (3.1/0.8)
##             purpose = repairs:
##             :...checking_balance in {< 0 DM,> 200 DM}: 2 (3.1)
##             :   checking_balance = 1 - 200 DM: 1 (14/5.6)
##             purpose = car (used):
##             :...amount <= 7253: 1 (34.5/6.1)
##             :   amount > 7253:
##             :   :...credit_history = critical: 1 (2.6)
##             :       credit_history in {delayed,repaid}: 2 (12.6/0.6)
##             purpose = education:
##             :...employment_length = unemployed: 2 (0)
##             :   employment_length = 4 - 7 yrs: 1 (5.7)
##             :   employment_length in {> 7 yrs,0 - 1 yrs,1 - 4 yrs}:
##             :   :...checking_balance = < 0 DM: 2 (9)
##             :       checking_balance in {> 200 DM,1 - 200 DM}:
##             :       :...residence_history <= 3: 2 (6.9/0.9)
##             :           residence_history > 3: 1 (8.9/1.7)
##             purpose = furniture:
```

```
##                   :...housing = for free: 1 (7.2/0.1)
##              :    housing in {own,rent}:
##              :    :...savings_balance in {> 1000 DM,unknown}: 1 (20.4/6.4)
##              :        savings_balance in {101 - 500 DM,
##              :        :                   501 - 1000 DM}: 2 (5.7)
##              :        savings_balance = < 100 DM:
##              :        :...employment_length in {> 7 yrs,0 - 1 yrs}: 1 (25.5/7.1)
##              :            employment_length in {4 - 7 yrs,
##              :            :                     unemployed}: 2 (17.1/5.2)
##              :            employment_length = 1 - 4 yrs:
##              :            :...age <= 24: 2 (7.8)
##              :                age > 24: 1 (20.4/6.7)
##          purpose = car (new):
##          :...installment_rate <= 2:
##          :   :...employment_length = > 7 yrs: 2 (10.4/2)
##          :   :   employment_length in {0 - 1 yrs,1 - 4 yrs,4 - 7 yrs,
##          :   :                     unemployed}: 1 (36/5.2)
##          :   installment_rate > 2:
##          :   :...savings_balance in {> 1000 DM,101 - 500 DM}: 1 (9.5/2.4)
##          :        savings_balance in {501 - 1000 DM,unknown}: 2 (13.1/4.2)
##          :        savings_balance = < 100 DM:
##          :        :...amount > 2348: 2 (18/0.9)
##          :            amount <= 2348:
##          :            :...personal_status = female: 2 (7.6/1.8)
##          :                personal_status in {divorced male,
##          :                :                    married male}: 1 (3.8)
##          :                personal_status = single male: [S1]
##          purpose = radio/tv:
##          :...employment_length in {> 7 yrs,4 - 7 yrs}:
##              :...months_loan_duration <= 39: 1 (39.3/3.4)
##              :   months_loan_duration > 39: 2 (5.5/0.4)
##              employment_length in {0 - 1 yrs,1 - 4 yrs,unemployed}:
##              :...existing_credits > 1: 2 (13.8/1.7)
##                  existing_credits <= 1:
##                  :...savings_balance in {> 1000 DM,101 - 500 DM,
##                      :                    unknown}: 2 (9.2/2.8)
##                      savings_balance = 501 - 1000 DM: 1 (9/2.6)
##                      savings_balance = < 100 DM:
##                      :...employment_length in {0 - 1 yrs,
##                          :                    unemployed}: 2 (22.2/6.1)
##                          employment_length = 1 - 4 yrs:
##                          :...months_loan_duration <= 15: 1 (15.6/1.9)
##                              months_loan_duration > 15: 2 (18.3/5.3)
##
## SubTree [S1]
##
## property in {building society savings,real estate}: 1 (23/7.4)
## property in {other,unknown/none}: 2 (10.5/0.6)
##
## -----  Trial 11:  -----
##
## Decision tree:
##
## purpose = domestic appliances: 2 (5.6/2.3)
```

```
## purpose = retraining: 1 (8.9/1.8)
## purpose = others:
## :...employment_length in {> 7 yrs,1 - 4 yrs}: 2 (10.7/3.5)
## :    employment_length in {0 - 1 yrs,4 - 7 yrs,unemployed}: 1 (4.8)
## purpose = education:
## :...savings_balance in {> 1000 DM,101 - 500 DM}: 2 (8.6/0.8)
## :    savings_balance in {501 - 1000 DM,unknown}: 1 (7.7/1.1)
## :    savings_balance = < 100 DM:
## :    :...installment_rate <= 1: 1 (3.9)
## :        installment_rate > 1:
## :        :...employment_length in {> 7 yrs,0 - 1 yrs,1 - 4 yrs,
## :        :                         unemployed}: 2 (23/6.5)
## :            employment_length = 4 - 7 yrs: 1 (6.9/1.6)
## purpose = radio/tv:
## :...installment_plan = stores:
## :    :...amount <= 2241: 2 (13.1/3.1)
## :    :   amount > 2241: 1 (4.1)
## :    installment_plan = bank:
## :    :...residence_history <= 1: 1 (4.9)
## :    :   residence_history > 1:
## :    :   :...age <= 39: 2 (24.2/9.1)
## :    :       age > 39: 1 (5.6)
## :    installment_plan = none:
## :    :...credit_history in {critical,delayed}: 1 (44.2/9.5)
## :        credit_history in {fully repaid,fully repaid this bank}: 2 (4.4)
## :        credit_history = repaid:
## :        :...amount <= 5866: 1 (116.5/40.4)
## :            amount > 5866: 2 (11.9/1.8)
## purpose = car (used):
## :...amount <= 3380: 1 (17.7)
## :    amount > 3380:
## :    :...installment_plan = bank: 1 (9/3.2)
## :        installment_plan = stores: 2 (2.9/0.4)
## :        installment_plan = none:
## :        :...personal_status in {divorced male,married male}: 1 (4.7/0.6)
## :            personal_status = female: 2 (9.4/3.7)
## :            personal_status = single male:
## :            :...property in {building society savings,
## :                :            unknown/none}: 2 (17.8/5.6)
## :                property in {other,real estate}: 1 (7.6)
## purpose = repairs:
## :...property = unknown/none: 2 (9)
## :    property in {building society savings,other,real estate}:
## :    :...installment_plan = bank: 1 (0)
## :        installment_plan = stores: 2 (2.8)
## :        installment_plan = none:
## :        :...installment_rate <= 3: 1 (5.2)
## :            installment_rate > 3:
## :            :...existing_credits <= 1: 2 (6.8/0.1)
## :                existing_credits > 1: 1 (8.7/1.8)
## purpose = business:
## :...savings_balance = > 1000 DM: 2 (6.1/3)
## :    savings_balance in {101 - 500 DM,501 - 1000 DM,unknown}: 1 (25/5.1)
## :    savings_balance = < 100 DM:
```

```
## :    :...housing = for free: 1 (1.5/0.4)
## :        housing = rent: 2 (7/0.2)
## :        housing = own:
## :        :...credit_history = delayed: 2 (18.1/1.5)
## :            credit_history in {critical,fully repaid,fully repaid this bank,
## :            :                        repaid}:
## :            :...residence_history <= 1: 1 (11)
## :                residence_history > 1:
## :                :...checking_balance in {< 0 DM,unknown}: 1 (11/2.8)
## :                    checking_balance in {> 200 DM,1 - 200 DM}: 2 (11.7/1.6)
## purpose = car (new):
## :...installment_plan in {bank,stores}: 2 (44.9/11.9)
## :   installment_plan = none:
## :   :...property in {building society savings,other}:
## :       :...credit_history in {fully repaid,fully repaid this bank,
## :       :   :                        repaid}: 2 (55.9/21)
## :       :   credit_history = critical:
## :       :   :...existing_credits <= 1: 1 (4.3)
## :       :   :   existing_credits > 1:
## :       :   :   :...months_loan_duration <= 11: 1 (6.3)
## :       :   :       months_loan_duration > 11: 2 (10.9/3)
## :       :   credit_history = delayed:
## :       :   :...residence_history <= 3: 1 (3.5)
## :       :       residence_history > 3:
## :       :       :...savings_balance in {< 100 DM,> 1000 DM,101 - 500 DM,
## :       :       :                        501 - 1000 DM}: 2 (10.6/0.3)
## :       :       savings_balance = unknown: 1 (4.3)
## :       property in {real estate,unknown/none}:
## :       :...checking_balance in {> 200 DM,1 - 200 DM,unknown}: 1 (37.8/7.6)
## :           checking_balance = < 0 DM:
## :           :...installment_rate <= 2: 1 (13.1)
## :               installment_rate > 2:
## :               :...amount <= 1198: 1 (4.4)
## :                   amount > 1198: 2 (14.1/1.8)
## purpose = furniture:
## :...installment_plan = stores: 1 (8.6)
##     installment_plan in {bank,none}:
##     :...other_debtors = guarantor: 1 (4.6)
##         other_debtors in {co-applicant,none}:
##         :...amount > 4042: 2 (40.9/8.2)
##             amount <= 4042:
##             :...amount > 3566: 1 (17.8)
##                 amount <= 3566:
##                 :...housing = for free: 1 (8.1/0.9)
##                     housing in {own,rent}:
##                     :...savings_balance = > 1000 DM: 1 (2.7)
##                         savings_balance in {101 - 500 DM,
##                         :                        501 - 1000 DM}: 2 (9.5/2.6)
##                         savings_balance = < 100 DM:
##                         :...amount <= 860: 1 (5.1)
##                         :   amount > 860: 2 (72.7/26.8)
##                         savings_balance = unknown:
##                         :...amount <= 2538: 1 (12.9/2.1)
##                             amount > 2538: 2 (5.2)
```

```
##
## -----  Trial 12:  -----
##
## Decision tree:
##
## checking_balance in {> 200 DM,unknown}:
## :...months_loan_duration <= 8:
## :    :...amount <= 4057: 1 (25.1)
## :    :   amount > 4057: 2 (2.5/0.2)
## :   months_loan_duration > 8:
## :   :...other_debtors = guarantor: 2 (5.2/2.1)
## :       other_debtors = co-applicant:
## :       :...credit_history = critical: 1 (3.6)
## :       :   credit_history in {delayed,fully repaid,fully repaid this bank,
## :       :                       repaid}: 2 (11.3/2.5)
## :       other_debtors = none:
## :       :...purpose in {car (used),domestic appliances,others,
## :       :               retraining}: 1 (25.7/3.4)
## :           purpose = repairs: 2 (9.1/3)
## :           purpose = business:
## :           :...residence_history <= 3: 2 (22.6/8.1)
## :           :   residence_history > 3: 1 (9.7/1.5)
## :           purpose = education:
## :           :...residence_history <= 2: 2 (6.7/2.2)
## :           :   residence_history > 2: 1 (13.8/2.7)
## :           purpose = furniture:
## :           :...months_loan_duration <= 30: 1 (50.4/9.9)
## :           :   months_loan_duration > 30: 2 (9/3.2)
## :           purpose = car (new):
## :           :...credit_history in {delayed,fully repaid this bank}: 1 (9.8/3.5)
## :           :   credit_history = fully repaid: 2 (2.3)
## :           :   credit_history = critical:
## :           :   :...residence_history <= 2: 2 (11.8/1.4)
## :           :   :   residence_history > 2: 1 (8.5)
## :           :   credit_history = repaid:
## :           :   :...housing = for free: 2 (5.1/1.2)
## :           :       housing in {own,rent}: 1 (18.3)
## :           purpose = radio/tv:
## :           :...months_loan_duration <= 9: 2 (8.6/0.6)
## :               months_loan_duration > 9:
## :               :...employment_length in {4 - 7 yrs,unemployed}: 1 (15.2)
## :                   employment_length in {> 7 yrs,0 - 1 yrs,1 - 4 yrs}:
## :                   :...installment_rate <= 2: 2 (15.3/5.5)
## :                       installment_rate > 2: 1 (47.9/13.7)
## checking_balance in {< 0 DM,1 - 200 DM}:
## :...months_loan_duration <= 30:
##     :...credit_history = fully repaid:
##     :   :...housing in {for free,rent}: 2 (5.9)
##     :   :   housing = own: 1 (13.9/5)
##     :   credit_history = fully repaid this bank:
##     :   :...age <= 23: 1 (6.2)
##     :   :   age > 23: 2 (27.3/6.8)
##     :   credit_history = critical:
##     :   :...installment_plan in {none,stores}: 1 (84.3/25.3)
```

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```
##      :    :      installment_plan = bank:
##      :    :      :...months_loan_duration <= 15: 1 (6)
##      :    :           months_loan_duration > 15: 2 (10.6/1.3)
##      :    credit_history = delayed:
##      :    :...employment_length = unemployed: 2 (6)
##      :    :    employment_length in {> 7 yrs,0 - 1 yrs,1 - 4 yrs,4 - 7 yrs}:
##      :    :    :...property = unknown/none: 2 (3.6)
##      :    :         property in {building society savings,other,real estate}:
##      :    :         :...savings_balance in {< 100 DM,101 - 500 DM,501 - 1000 DM,
##      :    :         :                        unknown}: 1 (20.6/2.9)
##      :    :              savings_balance = > 1000 DM: 2 (2.3)
##      :    credit_history = repaid:
##      :    :...savings_balance = > 1000 DM: 1 (3.7)
##      :         savings_balance = 501 - 1000 DM: 2 (12/5.1)
##      :         savings_balance = 101 - 500 DM:
##      :         :...personal_status in {divorced male,female,
##      :         :   :                     married male}: 2 (14.4/2.6)
##      :         :   personal_status = single male: 1 (8.2)
##      :         savings_balance = < 100 DM:
##      :         :...purpose in {business,car (used),domestic appliances,furniture,
##      :         :   :              others,repairs}: 1 (76.1/27.5)
##      :         :   purpose in {car (new),education,retraining}: 2 (49/19.6)
##      :         :   purpose = radio/tv:
##      :         :   :...housing in {for free,rent}: 2 (9.6/1.9)
##      :         :        housing = own: 1 (39/15.5)
##      :         savings_balance = unknown:
##      :         :...existing_credits > 1: 1 (2.5)
##      :              existing_credits <= 1:
##      :              :...personal_status in {divorced male,female,
##      :              :                         single male}: 1 (37.9/17)
##      :              personal_status = married male: 2 (5.3)
##      months_loan_duration > 30:
##      :...employment_length = unemployed: 1 (8.8)
##          employment_length in {> 7 yrs,0 - 1 yrs,1 - 4 yrs,4 - 7 yrs}:
##          :...savings_balance = > 1000 DM: 2 (0)
##              savings_balance = unknown: 1 (12.9/3.6)
##              savings_balance in {< 100 DM,101 - 500 DM,501 - 1000 DM}:
##              :...installment_plan in {bank,stores}: 2 (11.2/1.5)
##                  installment_plan = none:
##                  :...age <= 29: 2 (38/4.8)
##                      age > 29:
##                      :...property = building society savings: 1 (4.7)
##                          property in {other,real estate,unknown/none}:
##                          :...age <= 30: 1 (7.1/0.9)
##                              age > 30: 2 (35.2/9.3)
##
## -----  Trial 13:  -----
##
## Decision tree:
##
## checking_balance in {< 0 DM,1 - 200 DM}:
## :...employment_length = unemployed:
## :   :...housing = rent: 1 (6.5)
## :   :    housing = for free:
```

```
## :    :    :...personal_status = female: 2 (4.1/1.1)
## :    :    :   personal_status in {divorced male,married male,
## :    :    :                          single male}: 1 (10.9/1.3)
## :    :   housing = own:
## :    :   :...residence_history <= 2: 2 (14.3/0.8)
## :    :       residence_history > 2: 1 (14.3/4.4)
## :   employment_length = > 7 yrs:
## :   :...months_loan_duration > 40: 2 (7.9)
## :   :   months_loan_duration <= 40:
## :   :   :...purpose in {business,car (new),domestic appliances,
## :   :   :              education}: 2 (44/11.8)
## :   :       purpose in {others,repairs,retraining}: 1 (8.5/0.9)
## :   :       purpose = furniture:
## :   :       :...amount <= 1860: 1 (3.9)
## :   :       :   amount > 1860: 2 (19.3/4.9)
## :   :       purpose = radio/tv:
## :   :       :...amount <= 932: 2 (6.7/0.7)
## :   :       :   amount > 932: 1 (12.8)
## :   :       purpose = car (used):
## :   :       :...existing_credits > 1: 1 (3.5)
## :   :           existing_credits <= 1:
## :   :           :...housing = for free: 2 (12.7/3.3)
## :   :               housing in {own,rent}: 1 (2.9)
## :   employment_length = 0 - 1 yrs:
## :   :...other_debtors in {co-applicant,guarantor}: 1 (7/1.5)
## :   :   other_debtors = none:
## :   :   :...installment_rate <= 2: 2 (35.5/16.7)
## :   :       installment_rate > 2:
## :   :       :...residence_history > 1: 2 (44.1/9.3)
## :   :           residence_history <= 1:
## :   :           :...age <= 32: 1 (15.3/1.7)
## :   :               age > 32: 2 (6.4/1.3)
## :   employment_length = 1 - 4 yrs:
## :   :...other_debtors = guarantor: 1 (10.8/1.4)
## :   :   other_debtors in {co-applicant,none}:
## :   :   :...purpose in {car (new),car (used),retraining}: 1 (42.1/16.5)
## :   :       purpose in {domestic appliances,education,others,
## :   :       :              repairs}: 2 (22.1/6)
## :   :       purpose = business:
## :   :       :...months_loan_duration <= 21: 1 (3.4)
## :   :       :   months_loan_duration > 21: 2 (13.4/3.7)
## :   :       purpose = radio/tv:
## :   :       :...months_loan_duration <= 11: 1 (6.7)
## :   :       :   months_loan_duration > 11:
## :   :       :   :...credit_history in {critical,fully repaid,
## :   :       :   :              fully repaid this bank}: 2 (8.2/0.4)
## :   :       :       credit_history = delayed: 1 (2.1)
## :   :       :       credit_history = repaid:
## :   :       :       :...property in {building society savings,
## :   :       :       :              other}: 1 (14.1/3.9)
## :   :       :           property in {real estate,unknown/none}: 2 (16.7/0.8)
## :   :       purpose = furniture:
## :   :       :...housing in {for free,rent}: 2 (8.7/0.9)
## :   :           housing = own:
```

```
## :    :                   :...installment_plan in {bank,stores}: 1 (6.9/0.8)
## :    :                      installment_plan = none:
## :    :                      :...age <= 24: 2 (6.7)
## :    :                            age > 24:
## :    :                            :...checking_balance = < 0 DM: 1 (12.2/2)
## :    :                               checking_balance = 1 - 200 DM: 2 (9/2.5)
## :    employment_length = 4 - 7 yrs:
## :    :...checking_balance = 1 - 200 DM:
## :        :...housing = for free: 2 (3.3)
## :        :   housing = rent: 1 (15.8)
## :        :   housing = own:
## :        :   :...property = other: 1 (14.6/3)
## :        :       property in {building society savings,real estate,unknown/none}:
## :        :       :...months_loan_duration <= 36: 1 (11.2/2.6)
## :        :           months_loan_duration > 36: 2 (7.1/1)
## :        checking_balance = < 0 DM:
## :        :...credit_history = critical: 1 (6.7)
## :            credit_history in {delayed,fully repaid,fully repaid this bank,
## :            :                    repaid}:
## :            :...amount <= 1740: 2 (10.8/0.2)
## :                amount > 1740:
## :                :...months_loan_duration <= 22: 1 (6.6)
## :                    months_loan_duration > 22:
## :                    :...savings_balance = 101 - 500 DM: 1 (3.4)
## :                        savings_balance in {> 1000 DM,501 - 1000 DM,
## :                        :                    unknown}: 2 (2)
## :                        savings_balance = < 100 DM:
## :                        :...housing = for free: 1 (6/1.2)
## :                           housing in {own,rent}: 2 (13.6/2)
## checking_balance in {> 200 DM,unknown}:
## :...employment_length = unemployed:
##     :...installment_rate <= 2: 1 (5.8)
##     :   installment_rate > 2: 2 (11.8/3.1)
##     employment_length = 0 - 1 yrs:
##     :...other_debtors = co-applicant: 2 (3.7)
##     :   other_debtors = guarantor: 1 (1.6)
##     :   other_debtors = none:
##     :   :...amount > 4594: 2 (11.7/2)
##     :       amount <= 4594:
##     :       :...purpose in {business,car (new),car (used),domestic appliances,
##     :       :               education,furniture,others,radio/tv,
##     :       :               retraining}: 1 (32.3/4)
##     :           purpose = repairs: 2 (2.6)
##     employment_length = 4 - 7 yrs:
##     :...residence_history > 2: 1 (25/0.5)
##     :   residence_history <= 2:
##     :   :...age <= 23: 2 (5.7)
##     :       age > 23:
##     :       :...purpose in {business,car (used),domestic appliances,education,
##     :       :               furniture,others,radio/tv,repairs,
##     :       :               retraining}: 1 (14.5)
##     :           purpose = car (new): 2 (4.4/0.1)
##     employment_length = > 7 yrs:
##     :...credit_history in {critical,fully repaid,
```

```
##    :    :                       fully repaid this bank}: 1 (25.2/2.7)
##    :    credit_history = delayed: 2 (13.5/4.8)
##    :    credit_history = repaid:
##    :    :...property in {building society savings,real estate}: 1 (14.6)
##    :        property in {other,unknown/none}:
##    :        :...existing_credits > 1: 2 (8/0.9)
##    :            existing_credits <= 1:
##    :            :...amount <= 1264: 2 (5.1/0.3)
##    :                amount > 1264: 1 (16.2)
##    employment_length = 1 - 4 yrs:
##    :...months_loan_duration <= 7: 1 (12.1)
##        months_loan_duration > 7:
##        :...installment_rate <= 1: 1 (15.1/1.9)
##            installment_rate > 1:
##            :...installment_plan = bank: 2 (10.5/2.5)
##                installment_plan in {none,stores}:
##                :...installment_rate <= 2:
##                    :...existing_credits > 2: 2 (2.1)
##                    :   existing_credits <= 2:
##                    :   :...residence_history <= 1: 2 (4.7/1.3)
##                    :       residence_history > 1: 1 (20.6)
##                    installment_rate > 2:
##                    :...residence_history <= 1: 1 (4.3)
##                        residence_history > 1:
##                        :...checking_balance = > 200 DM: 2 (13.5/2.4)
##                            checking_balance = unknown:
##                            :...installment_rate <= 3: 1 (6.8)
##                                installment_rate > 3:
##                                :...installment_plan = stores: 2 (3.9)
##                                    installment_plan = none:
##                                    :...age <= 30: 2 (27/10.3)
##                                        age > 30: 1 (12.6)
##
## -----  Trial 14:  -----
##
## Decision tree:
##
## checking_balance = unknown:
## :...installment_plan = stores: 1 (14/4.9)
## :   installment_plan = bank:
## :   :...housing = for free: 1 (7.6/1.1)
## :   :   housing = rent: 2 (4.7/1.1)
## :   :   housing = own:
## :   :   :...savings_balance in {< 100 DM,> 1000 DM,101 - 500 DM,
## :   :   :                       501 - 1000 DM}: 1 (25.6/7.8)
## :   :       savings_balance = unknown: 2 (13.4/3.3)
## :   installment_plan = none:
## :   :...credit_history in {critical,fully repaid,
## :   :                      fully repaid this bank}: 1 (57.5/4.2)
## :       credit_history = repaid:
## :       :...existing_credits <= 1: 1 (80/15.8)
## :       :   existing_credits > 1:
## :       :   :...installment_rate <= 2: 2 (8.6/0.7)
## :       :       installment_rate > 2: 1 (7.2/0.7)
```

```
## :          credit_history = delayed:
## :          :...residence_history <= 1: 2 (3.5)
## :              residence_history > 1:
## :              :...installment_rate <= 3: 1 (13.2)
## :                  installment_rate > 3:
## :                  :...amount <= 1525: 1 (4)
## :                      amount > 1525:
## :                      :...age <= 57: 2 (13/3.2)
## :                          age > 57: 1 (2.2)
## checking_balance in {< 0 DM,> 200 DM,1 - 200 DM}:
## :...installment_rate <= 2:
##     :...amount > 11054: 2 (13.2/2.1)
##     :   amount <= 11054:
##     :   :...savings_balance in {> 1000 DM,501 - 1000 DM,unknown}: 1 (46.7/10.9)
##     :       savings_balance = 101 - 500 DM:
##     :       :...installment_plan = bank: 1 (5.9)
##     :       :   installment_plan in {none,stores}: 2 (21.5/7.9)
##     :       savings_balance = < 100 DM:
##     :       :...property = unknown/none: 1 (21.9/2.8)
##     :           property in {building society savings,other,real estate}:
##     :           :...purpose in {car (new),car (used),domestic appliances,
##     :           :               others,repairs,retraining}: 1 (44.2/12.3)
##     :               purpose = education: 2 (6/1.2)
##     :               purpose = business:
##     :               :...residence_history > 3: 2 (6.6/0.5)
##     :               :   residence_history <= 3: [S1]
##     :               purpose = furniture:
##     :               :...employment_length in {> 7 yrs,unemployed}: 1 (5.8)
##     :               :   employment_length in {0 - 1 yrs,1 - 4 yrs,4 - 7 yrs}: [S2]
##     :               purpose = radio/tv:
##     :               :...credit_history in {fully repaid,
##     :               :                      fully repaid this bank}: 2 (0)
##     :                   credit_history = delayed: 1 (3.5)
##     :                   credit_history in {critical,repaid}:
##     :                   :...installment_plan in {bank,stores}: 2 (1.3)
##     :                       installment_plan = none: [S3]
##     installment_rate > 2:
##     :...credit_history = fully repaid: 2 (13.7/1.1)
##         credit_history in {critical,delayed,fully repaid this bank,repaid}:
##         :...residence_history <= 1: 1 (40.4/13.1)
##             residence_history > 1:
##             :...personal_status in {divorced male,female}:
##                 :...amount > 3915: 2 (18.8)
##                 :   amount <= 3915:
##                 :   :...age <= 35: 2 (69.7/18.8)
##                 :       age > 35: 1 (21/2.5)
##                 personal_status in {married male,single male}:
##                 :...savings_balance in {> 1000 DM,101 - 500 DM}: 1 (23.7/7.2)
##                     savings_balance = 501 - 1000 DM: 2 (10.2/2.5)
##                     savings_balance = unknown:
##                     :...checking_balance = 1 - 200 DM: 1 (20.9)
##                         checking_balance in {< 0 DM,> 200 DM}:
##                         :...employment_length in {> 7 yrs,0 - 1 yrs,1 - 4 yrs,
##                         :   :                      unemployed}: 2 (18.1/4.9)
```

```
##                          :         employment_length = 4 - 7 yrs: 1 (3.2/0.3)
##                      savings_balance = < 100 DM:
##                      :...credit_history = delayed: 2 (14.8/1.9)
##                          credit_history in {critical,fully repaid this bank,
##                          :                       repaid}:
##                          :...months_loan_duration <= 11: 1 (21.3/2.2)
##                              months_loan_duration > 11:
##                              :...property in {other,unknown/none}:
##                                  :...other_debtors = co-applicant: 1 (2.6/0.4)
##                                  :   other_debtors = guarantor: 2 (1.8/0.6)
##                                  :   other_debtors = none:
##                                  :   :...housing = rent: 1 (3.5/0.4)
##                                  :       housing in {for free,own}:
##                                  :       :...existing_credits <= 1: 2 (37.1/4.9)
##                                  :           existing_credits > 1:
##                                  :           :...installment_rate <= 3: 1 (3.9)
##                                  :               installment_rate > 3: 2 (13.2/5.2)
##                                  property in {building society savings,
##                                  :             real estate}:
##                                  :...installment_plan in {bank,
##                                      :                     stores}: 2 (10.7/3.1)
##                                      installment_plan = none: [S4]
##
## SubTree [S1]
##
## credit_history in {critical,fully repaid,fully repaid this bank,
## :                   repaid}: 1 (11.9)
## credit_history = delayed: 2 (3.1)
##
## SubTree [S2]
##
## credit_history in {critical,delayed,fully repaid this bank}: 2 (10.5/0.6)
## credit_history = fully repaid: 1 (2.6/0.3)
## credit_history = repaid:
## :...employment_length in {0 - 1 yrs,4 - 7 yrs}: 1 (9.3/0.7)
##     employment_length = 1 - 4 yrs: 2 (18.5/7.5)
##
## SubTree [S3]
##
## property in {building society savings,real estate}: 2 (15.2/3.8)
## property = other: 1 (4.2)
##
## SubTree [S4]
##
## other_debtors = co-applicant: 2 (0.9)
## other_debtors = guarantor: 1 (3.6)
## other_debtors = none:
## :...property = real estate: 1 (14.5/1.5)
##     property = building society savings:
##     :...amount <= 1163: 2 (4.1)
##         amount > 1163:
##         :...residence_history <= 2: 2 (9/3.2)
##             residence_history > 2: 1 (12.9/2)
##
```

```
## -----  Trial 15:  -----
##
## Decision tree:
##
## months_loan_duration <= 7: 1 (56.4/9.9)
## months_loan_duration > 7:
## :...checking_balance in {> 200 DM,unknown}:
##     :...installment_plan = none: 1 (215.4/64.6)
##     :   installment_plan = stores:
##     :   :...installment_rate <= 3: 1 (4.3)
##     :   :   installment_rate > 3: 2 (13.1/4.7)
##     :   installment_plan = bank:
##     :   :...other_debtors = guarantor: 2 (0)
##     :       other_debtors = co-applicant: 1 (2.1)
##     :       other_debtors = none:
##     :       :...credit_history in {delayed,fully repaid this bank,
##     :       :                      repaid}: 1 (32.8/14.2)
##     :           credit_history = fully repaid: 2 (2.3)
##     :           credit_history = critical:
##     :           :...age <= 45: 2 (14.1/2.5)
##     :               age > 45: 1 (4.4)
##     checking_balance in {< 0 DM,1 - 200 DM}:
##     :...credit_history = delayed:
##         :...savings_balance = > 1000 DM: 2 (2.5)
##         :   savings_balance in {101 - 500 DM,501 - 1000 DM,
##         :   :                   unknown}: 1 (21.5/2.8)
##         :   savings_balance = < 100 DM:
##         :   :...months_loan_duration <= 20: 1 (9.5/0.8)
##         :       months_loan_duration > 20: 2 (14/2.7)
##         credit_history = fully repaid this bank:
##         :...age <= 23: 1 (5.4)
##         :   age > 23:
##         :   :...months_loan_duration <= 27: 2 (22/5.2)
##         :       months_loan_duration > 27: 1 (4.3/1)
##         credit_history = fully repaid:
##         :...housing in {for free,rent}: 2 (8.5)
##         :   housing = own:
##         :   :...installment_rate > 3: 2 (3.9)
##         :       installment_rate <= 3:
##         :       :...age <= 34: 1 (11.8/2.4)
##         :           age > 34: 2 (3)
##         credit_history = critical:
##         :...residence_history <= 1: 1 (7.3)
##         :   residence_history > 1:
##         :   :...savings_balance in {> 1000 DM,501 - 1000 DM}: 2 (9.1/2.5)
##         :       savings_balance in {101 - 500 DM,unknown}: 1 (10.3/1.9)
##         :       savings_balance = < 100 DM:
##         :       :...other_debtors = co-applicant: 2 (7.1/1.2)
##         :           other_debtors in {guarantor,none}:
##         :           :...months_loan_duration <= 36: 1 (77.2/25.6)
##         :               months_loan_duration > 36: 2 (4.5)
##         credit_history = repaid:
##         :...other_debtors = guarantor: 1 (16/3)
##             other_debtors in {co-applicant,none}:
```

```
##                 :...savings_balance = > 1000 DM: 1 (5.4)
##                     savings_balance in {< 100 DM,101 - 500 DM,501 - 1000 DM,
##                 :                           unknown}:
##                 :...purpose in {domestic appliances,retraining}: 2 (3.9/0.6)
##                     purpose in {education,others,repairs}: 1 (26.1/10.8)
##                     purpose = business:
##                     :...age <= 35: 1 (11.8/1.7)
##                     :   age > 35: 2 (6.7)
##                     purpose = car (used):
##                     :...amount <= 7228: 1 (17.7/3.2)
##                     :   amount > 7228: 2 (15.7/1.7)
##                     purpose = furniture:
##                     :...installment_plan = bank: 2 (5.3/0.9)
##                     :   installment_plan = stores: 1 (1.3)
##                     :   installment_plan = none:
##                     :   :...months_loan_duration <= 15: 1 (26.5/6.7)
##                     :       months_loan_duration > 15:
##                     :       :...installment_rate <= 1: 1 (8.8/2.2)
##                     :           installment_rate > 1: 2 (30.6/8.1)
##                     purpose = radio/tv:
##                     :...amount > 5324: 2 (6.8)
##                     :   amount <= 5324:
##                     :   :...property in {building society savings,
##                     :   :               unknown/none}: 2 (10.5/3)
##                     :       property = other:
##                     :       :...age <= 29: 1 (22.4/5.8)
##                     :       :   age > 29: 2 (8.9/1.5)
##                     :       property = real estate:
##                     :       :...months_loan_duration <= 11: 1 (4.1)
##                     :           months_loan_duration > 11: 2 (23.4/7.8)
##                     purpose = car (new):
##                     :...employment_length = unemployed: 1 (4.2)
##                         employment_length in {> 7 yrs,0 - 1 yrs,1 - 4 yrs,
##                     :                           4 - 7 yrs}:
##                     :...personal_status in {divorced male,
##                     :                       married male}: 2 (11.7/2.4)
##                         personal_status = female:
##                         :...amount <= 7882: 2 (25.8/1.6)
##                         :   amount > 7882: 1 (3.4)
##                         personal_status = single male:
##                         :...housing = rent: 1 (3.2)
##                             housing in {for free,own}: [S1]
##
## SubTree [S1]
##
## savings_balance = 501 - 1000 DM: 2 (0)
## savings_balance = unknown: 1 (2.4)
## savings_balance in {< 100 DM,101 - 500 DM}:
## :...other_debtors = co-applicant: 2 (3.8)
##     other_debtors = none:
##     :...installment_rate <= 2: 1 (8.3/1.9)
##         installment_rate > 2: 2 (18/3.6)
##
## -----  Trial 16:  -----
```

```
##
## Decision tree:
##
## purpose in {domestic appliances,others,retraining}: 1 (23.7/8.4)
## purpose = repairs:
## :...property = unknown/none: 2 (10.6)
## :    property in {building society savings,other,real estate}:
## :    :...amount <= 1995: 2 (13.5/3.4)
## :        amount > 1995: 1 (8.9)
## purpose = education:
## :...installment_rate <= 3: 1 (21.2/8.2)
## :    installment_rate > 3:
## :    :...age > 57: 1 (2.2)
## :        age <= 57:
## :        :...checking_balance in {< 0 DM,1 - 200 DM,unknown}: 2 (28.6/3.8)
## :            checking_balance = > 200 DM: 1 (2)
## purpose = business:
## :...savings_balance in {> 1000 DM,101 - 500 DM,501 - 1000 DM,
## :    :                    unknown}: 1 (31.6/7.4)
## :    savings_balance = < 100 DM:
## :    :...amount > 6681: 2 (11.9)
## :        amount <= 6681:
## :        :...residence_history <= 1: 1 (12/0.9)
## :            residence_history > 1:
## :            :...other_debtors = co-applicant: 2 (0)
## :                other_debtors = guarantor: 1 (1.3)
## :                other_debtors = none:
## :                :...existing_credits > 3: 1 (2)
## :                    existing_credits <= 3:
## :                    :...age <= 27: 1 (8.5/2)
## :                        age > 27: 2 (19.9/2.9)
## purpose = car (used):
## :...amount <= 3380: 1 (14.6)
## :    amount > 3380:
## :    :...credit_history in {critical,delayed}: 1 (14.6/2.4)
## :        credit_history in {fully repaid,fully repaid this bank}: 2 (6.5/1.9)
## :        credit_history = repaid:
## :        :...checking_balance = > 200 DM: 2 (0)
## :            checking_balance = unknown: 1 (3.8)
## :            checking_balance in {< 0 DM,1 - 200 DM}:
## :            :...personal_status = divorced male: 1 (1)
## :                personal_status in {female,married male}: 2 (6.6)
## :                personal_status = single male:
## :                :...checking_balance = 1 - 200 DM: 1 (3.1)
## :                    checking_balance = < 0 DM:
## :                    :...amount <= 6999: 1 (8.2/2.5)
## :                        amount > 6999: 2 (7.3)
## purpose = car (new):
## :...installment_plan = stores: 2 (5.4/1.2)
## :    installment_plan = bank:
## :    :...savings_balance in {< 100 DM,501 - 1000 DM,unknown}: 2 (30.4/4.7)
## :    :    savings_balance in {> 1000 DM,101 - 500 DM}: 1 (7.3/0.5)
## :    installment_plan = none:
## :    :...checking_balance = unknown: 1 (30/7.3)
```

```
## :          checking_balance in {< 0 DM,> 200 DM,1 - 200 DM}:
## :          :...residence_history <= 2:
## :               :...housing in {for free,rent}: 2 (11.6/2.4)
## :               :    housing = own:
## :               :    :...credit_history in {critical,
## :               :    :                       fully repaid this bank}: 2 (11/3)
## :               :         credit_history in {delayed,fully repaid}: 1 (3.4)
## :               :         credit_history = repaid:
## :               :         :...checking_balance = < 0 DM: 2 (19.5/2.3)
## :               :              checking_balance in {> 200 DM,1 - 200 DM}: 1 (18.8/6.6)
## :          residence_history > 2:
## :          :...property = real estate: 1 (18.3/1.3)
## :               property in {building society savings,other,unknown/none}:
## :               :...other_debtors = co-applicant: 2 (4.4/1.9)
## :                    other_debtors = guarantor: 1 (2.1)
## :                    other_debtors = none:
## :                    :...savings_balance in {> 1000 DM,501 - 1000 DM,
## :                    :                        unknown}: 1 (5.9/0.5)
## :                    savings_balance = 101 - 500 DM: 2 (14.8/5.6)
## :                    savings_balance = < 100 DM:
## :                    :...installment_rate > 3: 2 (15.1/1.3)
## :                         installment_rate <= 3:
## :                         :...months_loan_duration <= 22: 1 (13.9/2.8)
## :                              months_loan_duration > 22: 2 (2.3)
## purpose = furniture:
## :...installment_plan = stores: 1 (9.6)
## :    installment_plan in {bank,none}:
## :    :...savings_balance in {> 1000 DM,101 - 500 DM}: 1 (11.8/3.9)
## :         savings_balance = 501 - 1000 DM: 2 (11.4/3.9)
## :         savings_balance = unknown:
## :         :...existing_credits > 1: 1 (4)
## :         :    existing_credits <= 1:
## :         :    :...age <= 28: 2 (6.7/0.4)
## :         :         age > 28: 1 (8.9/1.6)
## :         savings_balance = < 100 DM:
## :         :...amount > 4281:
## :              :...other_debtors in {co-applicant,none}: 2 (25.6/1.9)
## :              :    other_debtors = guarantor: 1 (1.9)
## :              amount <= 4281:
## :              :...housing = for free: 1 (5.4)
## :                   housing in {own,rent}:
## :                   :...other_debtors = co-applicant: 2 (11.9/4.7)
## :                        other_debtors = guarantor: 1 (1.8)
## :                        other_debtors = none:
## :                        :...credit_history in {delayed,fully repaid,
## :                        :                       fully repaid this bank}: 2 (8.9/2.3)
## :                        credit_history = critical:
## :                        :...age > 53: 2 (3.7)
## :                        :    age <= 53: [S1]
## :                        credit_history = repaid:
## :                        :...employment_length in {> 7 yrs,0 - 1 yrs,
## :                             :                       4 - 7 yrs}: 1 (21.1/5.3)
## :                             employment_length = unemployed: 2 (4.6/1.9)
## :                             employment_length = 1 - 4 yrs:
```

```
## :                                :...personal_status in {divorced male,
## :                                :                          married male}: 1 (4.4)
## :                                personal_status = female: 2 (13.7/3.6)
## :                                personal_status = single male:
## :                                :...residence_history <= 1: 2 (3)
## :                                   residence_history > 1: 1 (15.3/5.2)
## purpose = radio/tv:
## :...months_loan_duration <= 8: 1 (12.1)
##     months_loan_duration > 8:
##     :...age <= 22:
##         :...age <= 21: 1 (7.9/2.6)
##         :   age > 21: 2 (16.9/0.6)
##         age > 22:
##         :...property = building society savings: 1 (22.1/4.9)
##             property = unknown/none: 2 (22.1/7.7)
##             property = other:
##             :...credit_history in {critical,delayed,
##             :   :                     fully repaid this bank}: 1 (19.5/7)
##             :   credit_history = fully repaid: 2 (2.8)
##             :   credit_history = repaid:
##             :   :...existing_credits > 1: 2 (16.8/4.9)
##             :       existing_credits <= 1:
##             :       :...months_loan_duration <= 33: 1 (26.9/3.9)
##             :           months_loan_duration > 33: 2 (13.7/5)
##             property = real estate:
##             :...checking_balance = unknown: 1 (9.8)
##                 checking_balance in {< 0 DM,> 200 DM,1 - 200 DM}:
##                 :...housing in {for free,rent}: 1 (8.3/1)
##                     housing = own:
##                     :...age <= 23: 1 (6.1)
##                         age > 23:
##                         :...installment_plan in {bank,stores}: 2 (6/1.3)
##                             installment_plan = none:
##                             :...employment_length = unemployed: 2 (0)
##                                 employment_length = > 7 yrs: 1 (6.2)
##                                 employment_length in {0 - 1 yrs,1 - 4 yrs,
##                                 :                        4 - 7 yrs}:
##                                 :...amount <= 1424: 1 (14.5/4.4)
##                                     amount > 1424: 2 (13.3/0.5)
##
## SubTree [S1]
##
## property in {building society savings,other,unknown/none}: 1 (15.6)
## property = real estate: 2 (7.6/1.1)
##
## -----  Trial 17:  -----
##
## Decision tree:
##
## checking_balance in {> 200 DM,unknown}:
## :...employment_length in {0 - 1 yrs,unemployed}:
## :   :...amount > 6681: 2 (10.9)
## :   :   amount <= 6681:
## :   :   :...other_debtors = co-applicant: 2 (8.3/1.1)
```

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```
## :    :           other_debtors = guarantor: 1 (0.7)
## :    :           other_debtors = none:
## :    :           :...savings_balance in {> 1000 DM,101 - 500 DM,501 - 1000 DM,
## :    :           :                          unknown}: 1 (11.4/1.7)
## :    :           savings_balance = < 100 DM:
## :    :           :...amount <= 1333: 1 (6.2)
## :    :               amount > 1333:
## :    :               :...checking_balance = > 200 DM: 2 (9.7/1.8)
## :    :                   checking_balance = unknown:
## :    :                   :...residence_history <= 3: 1 (9.3/2.7)
## :    :                       residence_history > 3: 2 (6.6/0.9)
## :    employment_length in {> 7 yrs,1 - 4 yrs,4 - 7 yrs}:
## :    :...months_loan_duration <= 8: 1 (18.3)
## :        months_loan_duration > 8:
## :        :...other_debtors = co-applicant: 1 (6/0.5)
## :            other_debtors = guarantor: 2 (6.9/2.2)
## :            other_debtors = none:
## :            :...installment_plan = bank:
## :                :...age <= 44: 2 (36.7/11.3)
## :                :   age > 44: 1 (8.5)
## :                installment_plan in {none,stores}:
## :                :...savings_balance = unknown: 1 (29.9/2.4)
## :                    savings_balance in {< 100 DM,> 1000 DM,101 - 500 DM,
## :                    :                      501 - 1000 DM}:
## :                    :...credit_history in {critical,fully repaid,
## :                       :                      fully repaid this bank}: 1 (35.6/6.7)
## :                        credit_history = delayed:
## :                        :...installment_rate <= 3: 1 (9.7)
## :                        :   installment_rate > 3:
## :                        :   :...existing_credits <= 1: 2 (5.7/0.1)
## :                        :       existing_credits > 1: [S1]
## :                        credit_history = repaid:
## :                        :...personal_status in {divorced male,
## :                           :                      married male}: 1 (5.3)
## :                            personal_status = female:
## :                            :...amount <= 1249: 2 (11.2/1.6)
## :                            :   amount > 1249:
## :                            :   :...months_loan_duration <= 30: 1 (11.6)
## :                            :       months_loan_duration > 30: 2 (3.2/0.8)
## :                            personal_status = single male:
## :                            :...existing_credits > 2: 2 (3.1)
## :                                existing_credits <= 2:
## :                                :...housing in {for free,rent}: 1 (9.1/1.6)
## :                                    housing = own:
## :                                    :...installment_plan = stores: 1 (3.6)
## :                                        installment_plan = none:
## :                                        :...age > 34: 1 (8.2)
## :                                            age <= 34:
## :                                            :...amount <= 4308: 2 (16/5.1)
## :                                                amount > 4308: 1 (4.8)
## checking_balance in {< 0 DM,1 - 200 DM}:
## :...property = real estate:
##     :...personal_status = divorced male: 2 (6.6/0.8)
##     :   personal_status in {female,married male,single male}:
```

```
##      :   :...months_loan_duration <= 11: 1 (24.9/1.8)
##      :       months_loan_duration > 11:
##      :       :...savings_balance in {> 1000 DM,101 - 500 DM}: 1 (8)
##      :           savings_balance in {< 100 DM,501 - 1000 DM,unknown}:
##      :           :...credit_history in {delayed,
##      :           :                      fully repaid this bank}: 1 (8.9/2.3)
##      :               credit_history = fully repaid: 2 (3.5/0.4)
##      :               credit_history = critical:
##      :               :...age <= 33: 2 (9/2.4)
##      :               :   age > 33: 1 (7.2)
##      :               credit_history = repaid:
##      :               :...age <= 23: 2 (8.5)
##      :                   age > 23:
##      :                   :...installment_plan = bank: 1 (7.3/1.1)
##      :                       installment_plan = stores: 2 (1.2)
##      :                       installment_plan = none:
##      :                       :...existing_credits > 1: 2 (4.1/0.4)
##      :                           existing_credits <= 1:
##      :                           :...installment_rate <= 1: 1 (7)
##      :                               installment_rate > 1: [S2]
##      property in {building society savings,other,unknown/none}:
##      :...amount > 7966: 2 (53.6/12)
##          amount <= 7966:
##          :...installment_rate <= 2:
##              :...amount <= 1534: 2 (28.1/7.9)
##              :   amount > 1534:
##              :   :...checking_balance = 1 - 200 DM: 1 (51.7/12)
##              :       checking_balance = < 0 DM:
##              :       :...months_loan_duration <= 15: 1 (10.2)
##              :           months_loan_duration > 15:
##              :           :...property = unknown/none: 1 (5.2)
##              :               property in {building society savings,other}:
##              :               :...residence_history <= 1: 2 (6.4)
##              :                   residence_history > 1:
##              :                   :...age <= 40: 1 (22.9/7.9)
##              :                       age > 40: 2 (8/0.2)
##          installment_rate > 2:
##          :...residence_history <= 1:
##              :...housing = rent: 2 (4.7/0.6)
##              :   housing in {for free,own}:
##              :   :...checking_balance = 1 - 200 DM: 1 (12.9/0.3)
##              :       checking_balance = < 0 DM:
##              :       :...savings_balance in {< 100 DM,> 1000 DM,
##              :       :                       501 - 1000 DM,
##              :       :                       unknown}: 1 (15.4/4.8)
##              :           savings_balance = 101 - 500 DM: 2 (2.8)
##              residence_history > 1:
##              :...credit_history in {fully repaid,
##              :                      fully repaid this bank}: 2 (22/4.2)
##                  credit_history = delayed:
##                  :...savings_balance in {< 100 DM,> 1000 DM,
##                  :   :                    501 - 1000 DM}: 2 (11.2)
##                  :   savings_balance in {101 - 500 DM,unknown}: 1 (11.6/2.1)
##                      credit_history = critical:
```

```
##                       :...property = unknown/none: 2 (9.4/1.1)
##                       :   property in {building society savings,other}:
##                       :   :...personal_status in {divorced male,
##                       :   :                       female}: 1 (10.5/1.1)
##                       :       personal_status = married male: 2 (8.6/2.9)
##                       :       personal_status = single male:
##                       :       :...age <= 25: 2 (3.7)
##                       :           age > 25:
##                       :           :...employment_length = > 7 yrs: 2 (14.6/5.8)
##                       :               employment_length in {0 - 1 yrs,1 - 4 yrs,
##                       :                                     4 - 7 yrs,
##                       :                                     unemployed}: 1 (15.7)
##                   credit_history = repaid:
##                   :...residence_history <= 2: 2 (46.1/5.8)
##                       residence_history > 2:
##                       :...other_debtors = co-applicant: 2 (1.9)
##                           other_debtors = guarantor: 1 (2.7)
##                           other_debtors = none:
##                           :...amount > 5804: 2 (6.2)
##                               amount <= 5804:
##                               :...employment_length = 0 - 1 yrs: 2 (11.6/1.6)
##                                   employment_length = unemployed: 1 (4.8)
##                                   employment_length in {> 7 yrs,1 - 4 yrs,
##                                   :                     4 - 7 yrs}: [S3]
##
## SubTree [S1]
##
## personal_status in {divorced male,married male}: 2 (0)
## personal_status = female: 1 (1.3)
## personal_status = single male:
## :...amount <= 2442: 1 (6.9/1.9)
##     amount > 2442: 2 (8.3)
##
## SubTree [S2]
##
## savings_balance = < 100 DM: 1 (19.9/6.1)
## savings_balance in {501 - 1000 DM,unknown}: 2 (10.9/2.9)
##
## SubTree [S3]
##
## savings_balance in {> 1000 DM,101 - 500 DM,501 - 1000 DM}: 1 (7.2)
## savings_balance in {< 100 DM,unknown}:
## :...installment_rate <= 3: 2 (9.8/1.2)
##     installment_rate > 3:
##     :...checking_balance = < 0 DM:
##         :...purpose in {business,car (used),furniture}: 1 (9.2)
##         :   purpose in {car (new),domestic appliances,education,others,
##         :               radio/tv,repairs,retraining}: 2 (16.4/2.6)
##         checking_balance = 1 - 200 DM:
##         :...residence_history <= 3: 2 (2.6)
##             residence_history > 3: 1 (12.2/0.3)
##
## -----  Trial 18:  -----
##
```

```
## Decision tree:
##
## checking_balance in {> 200 DM,unknown}:
## :...employment_length = 4 - 7 yrs:
## :   :...existing_credits <= 2: 1 (42.5/7.4)
## :   :   existing_credits > 2: 2 (3.4/0.5)
## :   employment_length = unemployed:
## :   :...property in {building society savings,unknown/none}: 1 (5.1)
## :   :   property in {other,real estate}: 2 (12.6/2.1)
## :   employment_length = > 7 yrs:
## :   :...existing_credits > 1: 1 (37/11.4)
## :   :   existing_credits <= 1:
## :   :   :...amount <= 1262: 2 (9.7/3.2)
## :   :         amount > 1262: 1 (25.3/1.4)
## :   employment_length = 0 - 1 yrs:
## :   :...other_debtors = co-applicant: 2 (3.3)
## :   :   other_debtors = guarantor: 1 (0.5)
## :   :   other_debtors = none:
## :   :   :...amount <= 6681: 1 (38.5/13.6)
## :   :         amount > 6681: 2 (5.5)
## :   employment_length = 1 - 4 yrs:
## :   :...installment_rate <= 1: 1 (18.8/1.2)
## :       installment_rate > 1:
## :       :...installment_plan in {bank,stores}: 2 (23.4/8.1)
## :           installment_plan = none:
## :           :...age <= 25: 1 (10.4)
## :               age > 25:
## :               :...checking_balance = > 200 DM: 2 (18.2/7.9)
## :                   checking_balance = unknown:
## :                   :...property = building society savings: 2 (11.4/5.3)
## :                       property = unknown/none: 1 (5.2)
## :                       property = other: [S1]
## :                       property = real estate:
## :                       :...purpose in {business,car (new),car (used),
## :                       :               domestic appliances,furniture,others,
## :                       :               radio/tv,repairs,retraining}: 1 (18.1)
## :                         purpose = education: 2 (4.4)
## checking_balance in {< 0 DM,1 - 200 DM}:
## :...other_debtors = guarantor:
##    :...months_loan_duration <= 15: 1 (14.6)
##    :   months_loan_duration > 15:
##    :   :...purpose in {business,car (new),domestic appliances,education,
##    :   :               radio/tv,repairs,retraining}: 2 (12.2/2.2)
##    :       purpose in {car (used),furniture,others}: 1 (6.6)
##    other_debtors = co-applicant:
##    :...savings_balance = unknown: 1 (5.4)
##    :   savings_balance in {> 1000 DM,101 - 500 DM,501 - 1000 DM}: 2 (5.3)
##    :   savings_balance = < 100 DM:
##    :   :...amount <= 2121: 1 (10.4)
##    :       amount > 2121:
##    :       :...installment_plan = stores: 2 (0)
##    :           installment_plan = bank: 1 (1.1)
##    :           installment_plan = none:
##    :           :...personal_status = divorced male: 1 (2.4)
```

```
##     :                          personal_status in {female,married male,
##     :                                    single male}: 2 (13.7/2.8)
##     other_debtors = none:
##     :...credit_history = fully repaid:
##         :...savings_balance in {< 100 DM,> 1000 DM,101 - 500 DM}: 2 (22.1/5)
##         :    savings_balance in {501 - 1000 DM,unknown}: 1 (4.4)
##         credit_history = fully repaid this bank:
##         :...personal_status in {divorced male,female}: 2 (11)
##         :    personal_status in {married male,single male}: 1 (18.4/6.2)
##         credit_history = critical:
##         :...purpose in {business,car (new),car (used),domestic appliances,
##         :    :              others,retraining}: 1 (57.3/12.6)
##         :    purpose in {education,repairs}: 2 (9.1/1.3)
##         :    purpose = furniture:
##         :    :...amount <= 1898: 1 (8.8)
##         :    :    amount > 1898: 2 (24.8/9.2)
##         :    purpose = radio/tv:
##         :    :...months_loan_duration <= 15: 1 (7.4)
##         :        months_loan_duration > 15: 2 (10.1/3)
##         credit_history = delayed:
##         :...installment_rate <= 1: 1 (9.8)
##         :    installment_rate > 1:
##         :    :...checking_balance = < 0 DM: 2 (11.7/1.3)
##         :        checking_balance = 1 - 200 DM:
##         :        :...housing in {for free,rent}: 1 (12.1/0.5)
##         :            housing = own:
##         :            :...installment_plan = bank: 1 (2.7)
##         :                installment_plan in {none,stores}: 2 (12.7/2.5)
##         credit_history = repaid:
##         :...savings_balance in {> 1000 DM,501 - 1000 DM}: 1 (18.8/3.6)
##             savings_balance in {< 100 DM,101 - 500 DM,unknown}:
##             :...amount > 8648:
##                 :...property in {building society savings,other,
##                 :    :              unknown/none}: 2 (16.2)
##                 :    property = real estate: 1 (2.1)
##                 amount <= 8648:
##                 :...purpose in {business,domestic appliances,education,
##                     :              retraining}: 2 (25.6/9.3)
##                     purpose in {others,repairs}: 1 (9.4/3.8)
##                     purpose = car (new):
##                     :...personal_status = divorced male: 2 (2.9)
##                     :    personal_status = married male: 1 (4.8/2.3)
##                     :    personal_status = female:
##                     :    :...installment_rate <= 2: 1 (10.6/3.6)
##                     :    :    installment_rate > 2: 2 (19.7/0.6)
##                     :    personal_status = single male:
##                     :    :...months_loan_duration <= 42: 1 (24.3/7.4)
##                     :        months_loan_duration > 42: 2 (3.3)
##                     purpose = car (used):
##                     :...checking_balance = 1 - 200 DM: 1 (5.8)
##                     :    checking_balance = < 0 DM:
##                     :    :...months_loan_duration <= 21: 2 (4.6)
##                     :        months_loan_duration > 21: 1 (10.6/2.1)
##                     purpose = furniture:
```

```
##                         :...housing = for free: 1 (4.6/1.1)
##                         :   housing = own:
##                         :   :...age <= 45: 2 (42/15.6)
##                         :   :    age > 45: 1 (3.9)
##                         :   housing = rent:
##                         :   :...months_loan_duration <= 22: 1 (10.7/3.7)
##                         :       months_loan_duration > 22: 2 (4.4)
##                     purpose = radio/tv:
##                     :...amount > 5324: 2 (6.4)
##                         amount <= 5324:
##                         :...installment_plan in {bank,stores}: 2 (9.8/2.6)
##                             installment_plan = none:
##                             :...savings_balance = 101 - 500 DM: 2 (7.2/1.8)
##                                 savings_balance = unknown: 1 (6.2/1.4)
##                                 savings_balance = < 100 DM:
##                                 :...installment_rate <= 2: 2 (8.2/1.8)
##                                     installment_rate > 2: 1 (31.7/10.1)
##
## SubTree [S1]
##
## credit_history in {critical,fully repaid}: 1 (5.6)
## credit_history in {delayed,fully repaid this bank,repaid}: 2 (13.1/3.5)
##
## -----  Trial 19:  -----
##
## Decision tree:
##
## months_loan_duration <= 7:
## :...amount <= 4113: 1 (49.8/5.6)
## :    amount > 4113: 2 (5.8/0.6)
## months_loan_duration > 7:
## :...employment_length = 0 - 1 yrs:
##     :...housing = for free: 1 (9/2.7)
##     :   housing = rent: 2 (39.8/10.1)
##     :   housing = own:
##     :   :...other_debtors = guarantor: 1 (2.8)
##     :       other_debtors = co-applicant: 2 (3.1/1.4)
##     :       other_debtors = none:
##     :       :...existing_credits > 1: 2 (31.6/11.2)
##     :           existing_credits <= 1:
##     :           :...age <= 25: 2 (22.5/4.3)
##     :               age > 25:
##     :               :...checking_balance = < 0 DM: 2 (23/7)
##     :                   checking_balance in {> 200 DM,1 - 200 DM,
##     :                                         unknown}: 1 (21.8/1.3)
##     employment_length in {> 7 yrs,1 - 4 yrs,4 - 7 yrs,unemployed}:
##     :...checking_balance in {> 200 DM,unknown}:
##         :...purpose in {car (used),domestic appliances,furniture,others,
##         :   :               retraining}: 1 (62.6/13.9)
##         :   purpose = repairs: 2 (6.5/2.6)
##         :   purpose = education:
##         :   :...installment_rate <= 3: 1 (3.4)
##         :   :   installment_rate > 3: 2 (12.6/5)
##         :   purpose = business:
```

```
##             :   :...employment_length = unemployed: 2 (4.1)
##             :   :   employment_length in {> 7 yrs,1 - 4 yrs,4 - 7 yrs}:
##             :   :   :...age <= 52: 1 (19.7/2.9)
##             :   :           age > 52: 2 (5/0.9)
##             :   purpose = car (new):
##             :   :...employment_length = 4 - 7 yrs: 2 (8.7/0.8)
##             :   :   employment_length = unemployed: 1 (2)
##             :   :   employment_length in {> 7 yrs,1 - 4 yrs}:
##             :   :   :...residence_history <= 3:
##             :   :           :...credit_history = critical: 2 (4.3/0.4)
##             :   :           :   credit_history in {delayed,fully repaid,
##             :   :           :                         fully repaid this bank,
##             :   :           :                         repaid}: 1 (12)
##             :   :           residence_history > 3:
##             :   :           :...age <= 49: 2 (12.8/2.2)
##             :   :                   age > 49: 1 (5.3)
##             :   purpose = radio/tv:
##             :   :...age > 35: 1 (22.3/4.2)
##             :       age <= 35:
##             :       :...months_loan_duration <= 9: 2 (7.2/1.7)
##             :           months_loan_duration > 9:
##             :           :...employment_length in {1 - 4 yrs,4 - 7 yrs}: 1 (37.3/4.3)
##             :               employment_length = unemployed: 2 (2.9/1)
##             :               employment_length = > 7 yrs:
##             :               :...age > 34: 2 (3.6)
##             :                   age <= 34:
##             :                   :...installment_rate <= 2: 2 (3.6/0.8)
##             :                       installment_rate > 2: 1 (13.6/2.2)
##       checking_balance in {< 0 DM,1 - 200 DM}:
##       :...credit_history = delayed: 1 (34.6/10.4)
##           credit_history = fully repaid:
##           :...installment_rate <= 3: 1 (14.4/5)
##           :   installment_rate > 3: 2 (5.6)
##           credit_history = fully repaid this bank:
##           :...installment_rate <= 1: 1 (3.4)
##           :   installment_rate > 1: 2 (30.1/9.6)
##           credit_history = repaid:
##           :...other_debtors = guarantor: 1 (16.1/2.4)
##           :   other_debtors in {co-applicant,none}:
##           :   :...purpose in {business,education,others,repairs,
##           :   :               retraining}: 1 (37.9/12.6)
##           :       purpose = domestic appliances: 2 (2.2)
##           :       purpose = car (used):
##           :       :...amount <= 7228: 1 (12.5/2.2)
##           :       :   amount > 7228: 2 (7.2)
##           :       purpose = radio/tv:
##           :       :...installment_rate <= 1: 1 (3.7)
##           :       :   installment_rate > 1:
##           :       :   :...employment_length = > 7 yrs: 1 (13/3.6)
##           :       :       employment_length in {1 - 4 yrs,4 - 7 yrs,
##           :       :                             unemployed}: 2 (41.9/13.8)
##           :       purpose = car (new):
##           :       :...employment_length = > 7 yrs: 2 (7.3/0.5)
##           :       :   employment_length = unemployed: 1 (3.1)
```

```
##              :           :      employment_length = 1 - 4 yrs:
##              :           :      :...amount <= 4169: 2 (19.9/4.7)
##              :           :      :   amount > 4169: 1 (2.4)
##              :           :      employment_length = 4 - 7 yrs:
##              :           :      :...amount <= 1721: 2 (4.9)
##              :           :          amount > 1721:
##              :           :          :...months_loan_duration <= 22: 1 (6.5)
##              :           :              months_loan_duration > 22: 2 (9.8/3)
##              :       purpose = furniture:
##              :       :...age <= 23: 2 (10.4)
##              :           age > 23:
##              :           :...installment_plan = bank: 2 (2.6)
##              :               installment_plan = stores: 1 (1.4)
##              :               installment_plan = none:
##              :               :...amount <= 4746: 1 (44.4/14.8)
##              :                   amount > 4746: 2 (3.8)
##          credit_history = critical:
##          :...months_loan_duration > 45: 2 (5.5)
##              months_loan_duration <= 45:
##              :...savings_balance in {> 1000 DM,101 - 500 DM,
##              :                       unknown}: 1 (11.4/1.1)
##                  savings_balance = 501 - 1000 DM: 2 (5.2/1.5)
##                  savings_balance = < 100 DM:
##                  :...residence_history <= 1: 1 (6.5)
##                      residence_history > 1:
##                      :...existing_credits <= 1: 2 (8.8/1.7)
##                          existing_credits > 1:
##                          :...existing_credits > 2: 1 (11.9/1.6)
##                              existing_credits <= 2:
##                              :...checking_balance = < 0 DM: 1 (33.5/10.1)
##                                  checking_balance = 1 - 200 DM:
##                                  :...age <= 43: 2 (14.7/3.8)
##                                      age > 43: 1 (4.7)
##
## -----  Trial 20:  -----
##
## Decision tree:
##
## checking_balance in {> 200 DM,unknown}:
## :...installment_plan = stores: 1 (20.8/7.6)
## :   installment_plan = bank:
## :   :...housing = for free: 1 (7.7/2.4)
## :   :   housing = rent: 2 (7.3/1.5)
## :   :   housing = own:
## :   :   :...savings_balance in {< 100 DM,> 1000 DM,101 - 500 DM,
## :   :   :                       501 - 1000 DM}: 1 (29.2/7.9)
## :   :       savings_balance = unknown: 2 (13.1/3.1)
## :   installment_plan = none:
## :   :...credit_history in {fully repaid,fully repaid this bank}: 1 (8.1/1.9)
## :       credit_history = critical:
## :       :...checking_balance = unknown: 1 (58.4/4.5)
## :       :   checking_balance = > 200 DM:
## :       :   :...months_loan_duration <= 11: 1 (4.3)
## :       :       months_loan_duration > 11: 2 (12.3/4.2)
```

```
## :        credit_history = delayed:
## :        :...installment_rate <= 3: 1 (10.5/0.8)
## :        :   installment_rate > 3:
## :        :   :...amount <= 1525: 1 (2.6)
## :        :        amount > 1525:
## :        :        :...savings_balance in {< 100 DM,> 1000 DM,
## :        :        :                       unknown}: 2 (17.7/1.3)
## :        :             savings_balance in {101 - 500 DM,
## :        :                                 501 - 1000 DM}: 1 (2.3)
## :        credit_history = repaid:
## :        :...existing_credits > 1:
## :             :...installment_rate <= 2: 2 (8.3/0.6)
## :             :   installment_rate > 2: 1 (7.6/1.9)
## :             existing_credits <= 1:
## :             :...purpose in {business,car (new),car (used),domestic appliances,
## :             :               education,others,retraining}: 1 (39.3/3.6)
## :                  purpose = repairs: 2 (3.2/0.6)
## :                  purpose = furniture:
## :                  :...age <= 27: 1 (10.3)
## :                  :   age > 27:
## :                  :   :...age <= 44: 2 (14.4/3.1)
## :                  :        age > 44: 1 (2.1)
## :                  purpose = radio/tv:
## :                  :...age > 28: 1 (16.3)
## :                      age <= 28:
## :                      :...months_loan_duration <= 10: 2 (4.5)
## :                          months_loan_duration > 10: 1 (17.8/6.3)
## checking_balance in {< 0 DM,1 - 200 DM}:
## :...savings_balance in {> 1000 DM,501 - 1000 DM,unknown}:
##     :...other_debtors in {co-applicant,guarantor}: 1 (6.1)
##     :   other_debtors = none:
##     :   :...months_loan_duration > 45: 1 (9.8)
##     :        months_loan_duration <= 45:
##     :        :...purpose in {business,car (used),retraining}: 1 (20.5/4.1)
##     :             purpose in {domestic appliances,education,others,
##     :             :           repairs}: 2 (12.2/2.7)
##     :             purpose = car (new):
##     :             :...residence_history <= 2: 2 (8.3/2.1)
##     :             :   residence_history > 2: 1 (9.3/1.9)
##     :             purpose = furniture:
##     :             :...installment_plan = bank: 2 (2.7/0.6)
##     :             :   installment_plan = stores: 1 (4.6)
##     :             :   installment_plan = none:
##     :             :   :...savings_balance in {> 1000 DM,unknown}: 1 (17.6/4.6)
##     :             :        savings_balance = 501 - 1000 DM: 2 (3.5)
##     :             purpose = radio/tv:
##     :             :...housing in {for free,rent}: 1 (5.3)
##     :                 housing = own:
##     :                 :...checking_balance = < 0 DM: 1 (4.1/0.4)
##     :                     checking_balance = 1 - 200 DM: 2 (11.3/4)
##     savings_balance in {< 100 DM,101 - 500 DM}:
##     :...months_loan_duration > 47: 2 (38.4/5.4)
##         months_loan_duration <= 47:
##         :...other_debtors = guarantor: 1 (23.5/5.3)
```

```
##                  other_debtors in {co-applicant,none}:
##                  :...purpose in {car (used),domestic appliances,others,
##                  :               retraining}: 1 (35.5/11.4)
##                     purpose in {education,repairs}: 2 (33.8/11.4)
##                     purpose = business:
##                     :...months_loan_duration <= 18: 1 (10.5)
##                     :   months_loan_duration > 18:
##                     :   :...housing in {for free,rent}: 2 (6.2)
##                     :       housing = own:
##                     :       :...amount <= 2292: 2 (5/0.1)
##                     :           amount > 2292: 1 (14.8/5.1)
##                     purpose = radio/tv:
##                     :...savings_balance = 101 - 500 DM: 2 (10.3/2.8)
##                     :   savings_balance = < 100 DM:
##                     :   :...employment_length in {> 7 yrs,4 - 7 yrs}: 1 (21.7/6.2)
##                     :       employment_length = unemployed: 2 (1)
##                     :       employment_length = 0 - 1 yrs:
##                     :       :...age <= 25: 2 (6.6)
##                     :       :   age > 25: 1 (16.3/5.3)
##                     :       employment_length = 1 - 4 yrs:
##                     :       :...housing = own: 1 (24.2/7.3)
##                     :           housing in {for free,rent}: 2 (7.7/0.5)
##                     purpose = car (new):
##                     :...employment_length in {> 7 yrs,0 - 1 yrs,unemployed}:
##                     :   :...installment_rate > 2: 2 (42.6/5.6)
##                     :   :   installment_rate <= 2:
##                     :   :   :...savings_balance = < 100 DM: 1 (14.5/4.1)
##                     :   :       savings_balance = 101 - 500 DM: 2 (2.9)
##                     :   employment_length in {1 - 4 yrs,4 - 7 yrs}:
##                     :   :...credit_history in {critical,delayed}: 1 (13/2.6)
##                     :       credit_history in {fully repaid,
##                     :       :                  fully repaid this bank}: 2 (5.3/2.2)
##                     :       credit_history = repaid:
##                     :       :...housing in {for free,rent}: 1 (12.1/3.3)
##                     :           housing = own:
##                     :           :...savings_balance = < 100 DM: 2 (12.8/2)
##                     :               savings_balance = 101 - 500 DM: 1 (3.9)
##                     purpose = furniture:
##                     :...savings_balance = 101 - 500 DM: 2 (7.5/1)
##                         savings_balance = < 100 DM:
##                         :...residence_history <= 1:
##                             :...employment_length in {> 7 yrs,0 - 1 yrs,1 - 4 yrs,
##                             :   :                      4 - 7 yrs}: 1 (14.5/0.3)
##                             :   employment_length = unemployed: 2 (2.9)
##                             residence_history > 1:
##                             :...existing_credits > 1:
##                                 :...age > 53: 2 (2.6)
##                                 :   age <= 53: [S1]
##                                 existing_credits <= 1:
##                                 :...age > 36: 2 (19.4/1.7)
##                                     age <= 36:
##                                     :...other_debtors = co-applicant: 1 (3.5)
##                                         other_debtors = none: [S2]
##
```

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```
## SubTree [S1]
##
## property in {building society savings,other}: 1 (14.4)
## property in {real estate,unknown/none}: 2 (4.8/0.8)
##
## SubTree [S2]
##
## personal_status in {divorced male,single male}: 1 (15.6/3)
## personal_status in {female,married male}: 2 (18.8/4.3)
##
## -----  Trial 21:  -----
##
## Decision tree:
##
## savings_balance in {> 1000 DM,101 - 500 DM,501 - 1000 DM,unknown}:
## :...personal_status in {divorced male,single male}:
## :   :...property in {other,real estate}:
## :   :   :...installment_plan in {none,stores}: 1 (76.9/6.6)
## :   :   :   installment_plan = bank:
## :   :   :   :...residence_history <= 2: 2 (13/4.2)
## :   :   :         residence_history > 2: 1 (12.1)
## :   :   property in {building society savings,unknown/none}:
## :   :   :...other_debtors = guarantor: 2 (3.5)
## :   :         other_debtors in {co-applicant,none}:
## :   :         :...checking_balance = < 0 DM: 2 (15.3/3.2)
## :   :               checking_balance in {> 200 DM,1 - 200 DM,unknown}:
## :   :               :...savings_balance = > 1000 DM: 2 (6/0.8)
## :   :                     savings_balance in {101 - 500 DM,501 - 1000 DM,
## :   :                                         unknown}: 1 (65.2/16.9)
## :   personal_status in {female,married male}:
## :   :...installment_plan in {bank,stores}: 2 (18.6/4.1)
## :         installment_plan = none:
## :         :...employment_length in {> 7 yrs,unemployed}: 1 (16.8/2.1)
## :               employment_length = 0 - 1 yrs:
## :               :...installment_rate <= 2: 1 (11.9/2.4)
## :               :   installment_rate > 2: 2 (9.2/1.9)
## :               employment_length = 4 - 7 yrs:
## :               :...checking_balance in {< 0 DM,> 200 DM}: 2 (7.6/1.7)
## :               :   checking_balance in {1 - 200 DM,unknown}: 1 (14.4)
## :               employment_length = 1 - 4 yrs:
## :               :...housing in {for free,rent}: 2 (13.5/0.8)
## :                     housing = own:
## :                     :...checking_balance = < 0 DM: 2 (6.5)
## :                           checking_balance in {> 200 DM,1 - 200 DM,unknown}:
## :                           :...existing_credits <= 1: 1 (18.2/3.7)
## :                                 existing_credits > 1: 2 (5.7/1.8)
## savings_balance = < 100 DM:
## :...amount > 7511:
##     :...age <= 29: 2 (23.8/0.2)
##     :   age > 29:
##     :   :...months_loan_duration <= 24: 2 (9.5)
##     :         months_loan_duration > 24:
##     :         :...months_loan_duration <= 47: 1 (12.7/2.9)
##     :               months_loan_duration > 47: 2 (4.1/0.6)
```

```
##      amount <= 7511:
##      :...credit_history in {delayed,fully repaid,fully repaid this bank}:
##          :...other_debtors = co-applicant: 1 (3.7)
##          :   other_debtors in {guarantor,none}:
##          :   :...installment_rate > 2: 2 (62.4/13.1)
##          :       installment_rate <= 2:
##          :       :...other_debtors = guarantor: 1 (1.6)
##          :           other_debtors = none:
##          :           :...checking_balance = < 0 DM: 2 (7.9/0.9)
##          :               checking_balance in {> 200 DM,unknown}: 1 (7.1)
##          :               checking_balance = 1 - 200 DM:
##          :               :...housing in {for free,rent}: 2 (5.2/0.9)
##          :                   housing = own: 1 (13.1/4.2)
##          credit_history in {critical,repaid}:
##          :...age > 46:
##              :...installment_plan in {bank,none}: 1 (49.9/8.2)
##              :   installment_plan = stores: 2 (3.6)
##              age <= 46:
##              :...installment_plan = stores:
##                  :...amount <= 2337: 2 (12.1/1)
##                  :   amount > 2337: 1 (7.6)
##                  installment_plan = bank:
##                  :...residence_history <= 1: 1 (6.1)
##                  :   residence_history > 1:
##                  :   :...amount <= 4933: 2 (37.4/8.2)
##                  :       amount > 4933: 1 (4.2/0.1)
##                  installment_plan = none:
##                  :...other_debtors = co-applicant: 2 (17.3/4.5)
##                      other_debtors = guarantor: 1 (14.6/2.7)
##                      other_debtors = none:
##                      :...checking_balance = unknown:
##                          :...months_loan_duration <= 33: 1 (47.5/6.2)
##                          :   months_loan_duration > 33: 2 (5.8/1.5)
##                          checking_balance in {< 0 DM,> 200 DM,1 - 200 DM}:
##                          :...purpose in {business,education,repairs,
##                              :                retraining}: 2 (35.5/15.1)
##                              purpose in {car (used),domestic appliances,
##                              :                others}: 1 (14.6/5.2)
##                              purpose = radio/tv:
##                              :...months_loan_duration <= 13: 1 (16.1/4.6)
##                              :   months_loan_duration > 13: 2 (43.3/14.3)
##                              purpose = car (new):
##                              :...personal_status = divorced male: 2 (4.6)
##                              :   personal_status = married male: 1 (6.4/2.3)
##                              :   personal_status = female:
##                              :   :...credit_history = critical: 1 (1.9)
##                              :   :   credit_history = repaid: 2 (13.9/3.7)
##                              :   personal_status = single male:
##                              :   :...installment_rate <= 2: 1 (5.4)
##                              :       installment_rate > 2: 2 (16.2/6.9)
##                              purpose = furniture:
##                              :...property = unknown/none: 1 (3.6)
##                                  property = building society savings: [S1]
##                                  property = real estate:
```

```
##                                              :...credit_history = critical: 2 (3.6)
##                                              :   credit_history = repaid:
##                                              :   :...age <= 24: 2 (4)
##                                              :       age > 24: 1 (11.5/1.8)
##                                          property = other:
##                                          :...existing_credits > 1: 1 (2.2)
##                                              existing_credits <= 1: [S2]
##
## SubTree [S1]
##
## personal_status in {divorced male,female,married male}: 1 (13.6)
## personal_status = single male: 2 (8.3/3.2)
##
## SubTree [S2]
##
## personal_status in {married male,single male}: 2 (6.3)
## personal_status in {divorced male,female}:
## :...credit_history = critical: 2 (0.9)
##     credit_history = repaid:
##     :...amount <= 1393: 2 (3.6)
##         amount > 1393: 1 (12.9/2)
##
## -----  Trial 22:  -----
##
## Decision tree:
##
## checking_balance = unknown:
## :...employment_length = > 7 yrs: 1 (54.4/14)
## :    employment_length = unemployed: 2 (14.3/5.3)
## :    employment_length = 1 - 4 yrs:
## :    :...months_loan_duration <= 9: 1 (15.9)
## :    :    months_loan_duration > 9:
## :    :    :...installment_plan in {bank,stores}: 2 (23.2/9.1)
## :    :        installment_plan = none: 1 (59.8/13.7)
## :    employment_length = 4 - 7 yrs:
## :    :...residence_history > 2: 1 (20.2)
## :    :    residence_history <= 2:
## :    :    :...age <= 23: 2 (5.1)
## :    :        age > 23: 1 (13.4/2.1)
## :    employment_length = 0 - 1 yrs:
## :    :...amount > 4594: 2 (12.3/0.8)
## :        amount <= 4594:
## :        :...other_debtors = guarantor: 1 (0)
## :            other_debtors = co-applicant: 2 (1.4)
## :            other_debtors = none:
## :            :...purpose in {business,car (new),car (used),domestic appliances,
## :                :             education,furniture,others,radio/tv,
## :                :             retraining}: 1 (20.9)
## :                purpose = repairs: 2 (3)
## checking_balance in {< 0 DM,> 200 DM,1 - 200 DM}:
## :...property = unknown/none:
##     :...employment_length in {> 7 yrs,1 - 4 yrs}: 2 (66.4/17.9)
##     :    employment_length = 0 - 1 yrs:
##     :    :...personal_status in {divorced male,married male,
```

```
##     :    :    :                              single male}: 2 (14.5/2.3)
##     :    :   personal_status = female: 1 (6/0.4)
##     :   employment_length = 4 - 7 yrs:
##     :   :...amount <= 2331: 2 (5.8)
##     :   :   amount > 2331: 1 (10.2/2.6)
##     :   employment_length = unemployed:
##     :   :...residence_history <= 1: 2 (2.5)
##     :       residence_history > 1: 1 (14.1/3.8)
##     property in {building society savings,other,real estate}:
##     :...purpose in {domestic appliances,others}: 2 (11.5/3.4)
##         purpose in {repairs,retraining}: 1 (24.1/5.9)
##         purpose = car (used):
##         :...amount <= 8086: 1 (15.6/4.1)
##         :   amount > 8086: 2 (5)
##         purpose = education:
##         :...checking_balance = < 0 DM: 2 (4.7)
##         :   checking_balance in {> 200 DM,1 - 200 DM}: 1 (14.8/3.6)
##         purpose = business:
##         :...months_loan_duration <= 18: 1 (18.6)
##         :   months_loan_duration > 18:
##         :   :...savings_balance = 501 - 1000 DM: 2 (0)
##         :       savings_balance in {> 1000 DM,101 - 500 DM,
##         :       :                    unknown}: 1 (11.6/2.1)
##         :       savings_balance = < 100 DM:
##         :       :...residence_history <= 1: 1 (5.6/1.2)
##         :           residence_history > 1: 2 (21.6/3.7)
##         purpose = car (new):
##         :...savings_balance in {> 1000 DM,501 - 1000 DM}: 1 (8.3/1.3)
##         :   savings_balance = 101 - 500 DM:
##         :   :...checking_balance in {< 0 DM,> 200 DM}: 1 (6.8)
##         :   :   checking_balance = 1 - 200 DM: 2 (14.2/3.7)
##         :   savings_balance = unknown:
##         :   :...amount <= 1372: 2 (5.5)
##         :   :   amount > 1372: 1 (12.3/3.3)
##         :   savings_balance = < 100 DM:
##         :   :...employment_length in {> 7 yrs,unemployed}: 2 (28.7/6.3)
##         :       employment_length in {1 - 4 yrs,4 - 7 yrs}: 1 (35.9/11.3)
##         :       employment_length = 0 - 1 yrs:
##         :       :...property in {building society savings,
##         :       :                 real estate}: 1 (17/6.4)
##         :           property = other: 2 (4.6)
##         purpose = furniture:
##         :...installment_plan = stores: 1 (5.8)
##         :   installment_plan in {bank,none}:
##         :   :...savings_balance = > 1000 DM: 1 (3.6)
##         :       savings_balance in {101 - 500 DM,501 - 1000 DM}: 2 (4.4)
##         :       savings_balance in {< 100 DM,unknown}:
##         :       :...months_loan_duration <= 7: 1 (5.7/1.2)
##         :           months_loan_duration > 7:
##         :           :...property = building society savings: 1 (50.6/15.6)
##         :               property = real estate: 2 (17.7/7.4)
##         :               property = other:
##         :               :...housing = for free: 2 (0)
##         :                   housing = rent: 1 (6.2/1)
```

```
##          :                        housing = own:
##          :                        :...months_loan_duration <= 15: 1 (6.9/1.2)
##          :                             months_loan_duration > 15: 2 (20.3/2.7)
##          purpose = radio/tv:
##          :...months_loan_duration > 36: 2 (14.9/1.8)
##              months_loan_duration <= 36:
##              :...employment_length in {> 7 yrs,4 - 7 yrs}:
##                  :...amount <= 932: 2 (8.9/2.4)
##                  :   amount > 932: 1 (35/1.5)
##                  employment_length in {0 - 1 yrs,1 - 4 yrs,unemployed}:
##                  :...other_debtors = guarantor: 1 (3.7)
##                      other_debtors in {co-applicant,none}:
##                      :...property = building society savings: 2 (6.8/2)
##                          property = real estate:
##                          :...months_loan_duration <= 30: 2 (38.4/12.2)
##                          :   months_loan_duration > 30: 1 (2.5)
##                          property = other:
##                          :...residence_history <= 1: 1 (12.8/2.1)
##                              residence_history > 1:
##                              :...installment_rate <= 3: 1 (10.9/0.7)
##                                  installment_rate > 3: 2 (15.3/1.2)
##
## -----  Trial 23:  -----
##
## Decision tree:
##
## checking_balance in {> 200 DM,unknown}:
## :...purpose in {business,car (used),domestic appliances,others,
## :   :              retraining}: 1 (61.1/13.4)
## :   purpose = repairs: 2 (10/4.7)
## :   purpose = furniture:
## :   :...months_loan_duration <= 30: 1 (46.7/11.5)
## :   :   months_loan_duration > 30: 2 (7/1.1)
## :   purpose = education:
## :   :...personal_status = married male: 1 (0)
## :   :   personal_status = divorced male: 2 (2.5)
## :   :   personal_status in {female,single male}:
## :   :   :...checking_balance = > 200 DM: 1 (3.8)
## :   :       checking_balance = unknown:
## :   :       :...installment_rate <= 3: 1 (3.8)
## :   :           installment_rate > 3: 2 (13.1/4.5)
## :   purpose = car (new):
## :   :...months_loan_duration <= 9: 1 (10.6)
## :   :   months_loan_duration > 9:
## :   :   :...installment_plan in {bank,stores}: 2 (14.5/3.3)
## :   :       installment_plan = none:
## :   :       :...existing_credits > 2: 2 (2.1)
## :   :           existing_credits <= 2:
## :   :           :...other_debtors in {co-applicant,none}: 1 (31.9/5.5)
## :   :               other_debtors = guarantor: 2 (4.3/0.7)
## :   purpose = radio/tv:
## :   :...personal_status in {divorced male,married male}: 1 (8.5)
## :       personal_status in {female,single male}:
## :       :...other_debtors = guarantor: 1 (0)
```

```
## :               other_debtors = co-applicant: 2 (5.2/1.6)
## :               other_debtors = none:
## :               :...credit_history in {delayed,
## :               :                      fully repaid this bank}: 1 (11.8/2.9)
## :                   credit_history = fully repaid: 2 (1.9)
## :                   credit_history = critical:
## :                   :...existing_credits <= 1: 2 (3.8/1.1)
## :                   :   existing_credits > 1: 1 (16.5/3)
## :                   credit_history = repaid:
## :                   :...installment_rate <= 3:
## :                      :...existing_credits <= 1: 1 (12.2/4.2)
## :                      :   existing_credits > 1: 2 (10.3)
## :                      installment_rate > 3:
## :                      :...months_loan_duration <= 10: 2 (2.5)
## :                          months_loan_duration > 10: 1 (22.1/2.2)
## checking_balance in {< 0 DM,1 - 200 DM}:
## :...credit_history = delayed:
##     :...installment_plan = stores: 2 (9.2/0.7)
##     :   installment_plan in {bank,none}:
##     :   :...checking_balance = < 0 DM: 2 (11.8/3.3)
##     :       checking_balance = 1 - 200 DM: 1 (31.3/7.1)
##     credit_history = fully repaid:
##     :...housing in {for free,rent}: 2 (12.8)
##     :   housing = own:
##     :   :...age <= 34: 1 (13.1/3.6)
##     :       age > 34: 2 (7.6)
##     credit_history = fully repaid this bank:
##     :...other_debtors = co-applicant: 1 (4)
##     :   other_debtors in {guarantor,none}:
##     :   :...property in {building society savings,unknown/none}: 2 (14.3/1)
##     :       property = real estate: 1 (5.4/1.3)
##     :       property = other:
##     :       :...checking_balance = < 0 DM: 2 (12.1/4.6)
##     :           checking_balance = 1 - 200 DM: 1 (3.1)
##     credit_history = critical:
##     :...residence_history <= 1: 1 (9.3)
##     :   residence_history > 1:
##     :   :...savings_balance = unknown: 1 (8.1)
##     :       savings_balance in {< 100 DM,> 1000 DM,101 - 500 DM,501 - 1000 DM}:
##     :       :...other_debtors in {co-applicant,guarantor}: 2 (14.2/3.8)
##     :           other_debtors = none:
##     :           :...purpose in {business,car (used),domestic appliances,others,
##     :           :               radio/tv,retraining}: 1 (34.2/8.8)
##     :               purpose in {education,repairs}: 2 (11.2/2.9)
##     :               purpose = car (new):
##     :               :...months_loan_duration <= 27: 1 (24.3/5)
##     :               :   months_loan_duration > 27: 2 (4.7)
##     :               purpose = furniture:
##     :               :...amount <= 1898: 1 (5.1)
##     :                   amount > 1898: 2 (17.1/4.6)
##     credit_history = repaid:
##     :...amount > 8086: 2 (29.1/4.3)
##         amount <= 8086:
##         :...savings_balance = > 1000 DM: 1 (6.5)
```

```
##                savings_balance in {< 100 DM,101 - 500 DM,501 - 1000 DM,unknown}:
##                :...months_loan_duration <= 8: 1 (17.6/2.3)
##                    months_loan_duration > 8:
##                    :...purpose in {business,education,others,
##                    :               repairs}: 1 (37.1/14.1)
##                        purpose in {domestic appliances,retraining}: 2 (5.6/0.7)
##                        purpose = radio/tv:
##                        :...amount <= 5324: 1 (77.4/31.4)
##                        :   amount > 5324: 2 (6.7)
##                        purpose = car (used):
##                        :...installment_plan in {bank,stores}: 1 (4.7)
##                        :   installment_plan = none:
##                        :   :...residence_history <= 3: 1 (3.9)
##                        :       residence_history > 3: 2 (12.1/2.5)
##                        purpose = furniture:
##                        :...installment_plan = bank: 2 (4.8/1.3)
##                        :   installment_plan = stores: 1 (0.6)
##                        :   installment_plan = none:
##                        :   :...property in {real estate,unknown/none}: 1 (14.5/3.5)
##                        :       property = building society savings:
##                        :       :...age <= 30: 1 (15.9/1.9)
##                        :       :   age > 30: 2 (11.6/3.1)
##                        :       property = other:
##                        :       :...months_loan_duration > 22: 2 (5.8)
##                        :           months_loan_duration <= 22:
##                        :           :...employment_length in {> 7 yrs,0 - 1 yrs,
##                        :           :                         4 - 7 yrs}: 1 (6)
##                        :               employment_length in {1 - 4 yrs,
##                        :                                     unemployed}: 2 (11/2.4)
##                        purpose = car (new):
##                        :...employment_length = unemployed: 1 (4)
##                            employment_length in {> 7 yrs,0 - 1 yrs,1 - 4 yrs,
##                            :                     4 - 7 yrs}:
##                            :...personal_status in {divorced male,female,
##                            :                       married male}: 2 (35.6/5.9)
##                                personal_status = single male:
##                                :...housing = rent: 1 (2.8)
##                                    housing in {for free,own}:
##                                    :...other_debtors in {co-applicant,
##                                    :                     guarantor}: 2 (3.6/0.9)
##                                        other_debtors = none:
##                                        :...installment_rate <= 2: 1 (6.2)
##                                            installment_rate > 2: 2 (17.7/5)
##
## -----  Trial 24:  -----
##
## Decision tree:
##
## credit_history = critical:
## :...age > 60: 1 (12.9)
## :    age <= 60:
## :    :...months_loan_duration <= 11: 1 (35.6/4)
## :        months_loan_duration > 11:
## :        :...savings_balance = > 1000 DM: 1 (5.4)
```

```
## :            savings_balance = 501 - 1000 DM: 2 (11.5/4.9)
## :            savings_balance = 101 - 500 DM:
## :            :...existing_credits <= 1: 1 (6.3)
## :            :   existing_credits > 1: 2 (9.1/1.8)
## :            savings_balance = unknown:
## :            :...housing = for free: 2 (3.9/0.1)
## :            :   housing in {own,rent}:
## :            :   :...amount <= 886: 2 (2.2)
## :            :       amount > 886: 1 (18.2/0.5)
## :            savings_balance = < 100 DM:
## :            :...installment_rate <= 1: 1 (7.1)
## :                installment_rate > 1:
## :                :...months_loan_duration > 42: 2 (6)
## :                    months_loan_duration <= 42:
## :                    :...age > 59: 2 (6.4)
## :                        age <= 59:
## :                        :...purpose in {business,car (used),
## :                        :               domestic appliances,education,others,
## :                        :               radio/tv,retraining}: 1 (52.3/13.5)
## :                            purpose in {car (new),repairs}: 2 (28.8/8.5)
## :                            purpose = furniture:
## :                            :...amount <= 7865: 1 (18.5/4.2)
## :                                amount > 7865: 2 (2.2)
## credit_history in {delayed,fully repaid,fully repaid this bank,repaid}:
## :...checking_balance in {> 200 DM,unknown}:
##     :...purpose in {car (used),domestic appliances,education,others,repairs,
##     :   :             retraining}: 1 (37.3/9.9)
##     :   purpose = business:
##     :   :...employment_length = 4 - 7 yrs: 1 (5.4)
##     :   :   employment_length in {> 7 yrs,0 - 1 yrs,1 - 4 yrs,unemployed}:
##     :   :   :...personal_status in {divorced male,married male,
##     :   :   :                       single male}: 2 (18.1/3)
##     :   :       personal_status = female: 1 (2.8)
##     :   purpose = car (new):
##     :   :...residence_history <= 2: 1 (13.8)
##     :   :   residence_history > 2:
##     :   :   :...checking_balance = > 200 DM: 2 (4.7)
##     :   :       checking_balance = unknown: 1 (17.8/7.5)
##     :   purpose = radio/tv:
##     :   :...property in {building society savings,unknown/none}: 1 (4.9)
##     :   :   property = real estate:
##     :   :   :...checking_balance = > 200 DM: 2 (10.6/3.2)
##     :   :   :   checking_balance = unknown: 1 (13.2/1.4)
##     :   :   property = other:
##     :   :   :...existing_credits <= 1:
##     :   :       :...age <= 27: 2 (7.6/2.6)
##     :   :       :   age > 27: 1 (10.9)
##     :   :       existing_credits > 1:
##     :   :       :...months_loan_duration <= 42: 2 (15.1/1.5)
##     :   :           months_loan_duration > 42: 1 (2.4)
##     :   purpose = furniture:
##     :   :...other_debtors in {co-applicant,guarantor}: 2 (2.8)
##     :       other_debtors = none:
##     :       :...age > 34: 1 (7.7)
```

```
##     :                 age <= 34:
##     :                 :...months_loan_duration > 30: 2 (3.4)
##     :                     months_loan_duration <= 30:
##     :                     :...months_loan_duration <= 18: 2 (21.2/6.8)
##     :                         months_loan_duration > 18: 1 (6)
##     checking_balance in {< 0 DM,1 - 200 DM}:
##     :...other_debtors = guarantor: 1 (20.1/5.6)
##         other_debtors = co-applicant:
##         :...savings_balance in {< 100 DM,> 1000 DM,501 - 1000 DM,
##         :   :                   unknown}: 1 (18.7/4.4)
##         :   savings_balance = 101 - 500 DM: 2 (3.1)
##         other_debtors = none:
##         :...savings_balance = > 1000 DM: 1 (9/2.8)
##             savings_balance = 501 - 1000 DM:
##             :...installment_rate <= 2: 1 (4.9)
##             :   installment_rate > 2: 2 (11.2/4.8)
##             savings_balance = 101 - 500 DM:
##             :...personal_status in {divorced male,female,
##             :   :                   married male}: 2 (22/4.2)
##             :   personal_status = single male:
##             :   :...existing_credits > 3: 2 (2.6)
##             :       existing_credits <= 3:
##             :       :...property in {other,real estate}: 1 (12.1)
##             :           property in {building society savings,unknown/none}:
##             :           :...employment_length in {> 7 yrs,
##             :           :                         unemployed}: 1 (6.4)
##             :               employment_length in {0 - 1 yrs,1 - 4 yrs,
##             :                                     4 - 7 yrs}: 2 (10.3/2.1)
##             savings_balance = unknown:
##             :...credit_history in {delayed,fully repaid}: 1 (6.9)
##             :   credit_history = fully repaid this bank: 2 (3)
##             :   credit_history = repaid:
##             :   :...existing_credits > 1: 1 (4.8)
##             :       existing_credits <= 1:
##             :       :...personal_status = divorced male: 1 (3.6)
##             :           personal_status = married male: 2 (6/1.3)
##             :           personal_status = female:
##             :           :...installment_rate <= 3: 1 (9.6/1.8)
##             :           :   installment_rate > 3: 2 (9.8/1.5)
##             :           personal_status = single male:
##             :           :...amount <= 5848: 1 (12.8/1.8)
##             :               amount > 5848: 2 (9.4)
##             savings_balance = < 100 DM:
##             :...credit_history = fully repaid: 2 (23.7/4.4)
##                 credit_history = fully repaid this bank:
##                 :...personal_status in {divorced male,female}: 2 (6.3)
##                 :   personal_status in {married male,single male}: 1 (9.1/2.3)
##                 credit_history = delayed:
##                 :...installment_rate <= 1: 1 (3.1)
##                 :   installment_rate > 1:
##                 :   :...employment_length in {> 7 yrs,0 - 1 yrs,4 - 7 yrs,
##                 :   :                         unemployed}: 2 (16.6/0.3)
##                 :       employment_length = 1 - 4 yrs: 1 (9.6/3.5)
##                 credit_history = repaid:
```

```
##                    :...residence_history <= 1:
##                        :...employment_length in {> 7 yrs,unemployed}: 2 (2.4/0.4)
##                        :   employment_length in {1 - 4 yrs,4 - 7 yrs}: 1 (8.1/1.3)
##                        :   employment_length = 0 - 1 yrs:
##                        :   :...amount <= 1237: 1 (6.4)
##                        :       amount > 1237:
##                        :       :...purpose in {car (used),domestic appliances,
##                        :       :              education,others,
##                        :       :              retraining}: 2 (0)
##                        :           purpose in {business,furniture}: 1 (6.7)
##                        :           purpose in {car (new),radio/tv,repairs}:
##                        :           :...amount <= 3959: 2 (14.5/0.8)
##                        :               amount > 3959: 1 (4.4/1)
##                    residence_history > 1:
##                    :...months_loan_duration > 39: 2 (14.6/1)
##                        months_loan_duration <= 39:
##                        :...personal_status = divorced male: 2 (9.5/3.5)
##                            personal_status = married male:
##                            :...employment_length in {> 7 yrs,
##                            :   :                     unemployed}: 1 (0)
##                            :   employment_length = 4 - 7 yrs: 2 (4.2)
##                            :   employment_length in {0 - 1 yrs,1 - 4 yrs}:
##                            :   :...installment_plan = bank: 2 (2.5)
##                            :       installment_plan in {none,
##                            :                            stores}: 1 (12.6/0.9)
##                            personal_status = female:
##                            :...residence_history <= 3: 2 (13.4)
##                            :   residence_history > 3:
##                            :   :...installment_rate <= 2:
##                            :       :...amount <= 1338: 2 (3)
##                            :       :   amount > 1338: 1 (13/1.3)
##                            :           installment_rate > 2:
##                            :           :...age > 54: 1 (2.6)
##                            :               age <= 54: [S1]
##                            personal_status = single male:
##                            :...installment_rate <= 3: 1 (28.2/10.4)
##                                installment_rate > 3:
##                                :...residence_history <= 2: 2 (17.2/0.7)
##                                    residence_history > 2:
##                                    :...months_loan_duration > 21: 1 (6)
##                                        months_loan_duration <= 21:
##                                        :...age <= 27: 1 (3.5)
##                                            age > 27: [S2]
##
## SubTree [S1]
##
## employment_length = > 7 yrs: 1 (2.2)
## employment_length in {0 - 1 yrs,1 - 4 yrs,4 - 7 yrs,unemployed}: 2 (21.6/1.3)
##
## SubTree [S2]
##
## purpose in {business,car (new),car (used),domestic appliances,education,
## :            furniture,others,radio/tv,retraining}: 2 (14.1)
## purpose = repairs: 1 (2.2)
```

```
##
## -----  Trial 25:  -----
##
## Decision tree:
##
## checking_balance in {> 200 DM,unknown}:
## :...installment_plan = stores:
## :   :...installment_rate <= 3: 1 (5.7)
## :   :   installment_rate > 3: 2 (13.2/4.3)
## :   installment_plan = bank:
## :   :...other_debtors in {co-applicant,guarantor}: 1 (1.9)
## :   :   other_debtors = none:
## :   :   :...housing = for free: 1 (7.1/2.5)
## :   :       housing = rent: 2 (5.4/1.1)
## :   :       housing = own:
## :   :       :...purpose in {business,car (new),car (used),domestic appliances,
## :   :       :               education,others,repairs,retraining}: 2 (24/8.3)
## :   :           purpose in {furniture,radio/tv}: 1 (20.2/4.3)
## :   installment_plan = none:
## :   :...credit_history in {fully repaid,fully repaid this bank}: 1 (7.3/1.2)
## :       credit_history = delayed:
## :       :...installment_rate <= 3: 1 (12.8/1.6)
## :       :   installment_rate > 3: 2 (23.6/6.8)
## :       credit_history = repaid:
## :       :...other_debtors in {co-applicant,guarantor}: 2 (13.5/4.8)
## :       :   other_debtors = none: 1 (110.1/31)
## :       credit_history = critical:
## :       :...checking_balance = unknown: 1 (62.9/5)
## :           checking_balance = > 200 DM:
## :           :...months_loan_duration <= 22: 2 (10.1/2.6)
## :               months_loan_duration > 22: 1 (6)
## checking_balance in {< 0 DM,1 - 200 DM}:
## :...savings_balance = 501 - 1000 DM: 1 (26.4/7.6)
##     savings_balance = > 1000 DM:
##     :...purpose in {business,car (new),car (used),domestic appliances,
##     :   :               furniture,others,radio/tv,retraining}: 1 (8)
##     :   purpose in {education,repairs}: 2 (6.8)
##     savings_balance = 101 - 500 DM:
##     :...other_debtors = co-applicant: 2 (2.5)
##     :   other_debtors = guarantor: 1 (1.1)
##     :   other_debtors = none:
##     :   :...age <= 41: 1 (52.2/18.2)
##     :       age > 41: 2 (6.5/0.1)
##     savings_balance = unknown:
##     :...credit_history in {critical,delayed,fully repaid}: 1 (10.7)
##     :   credit_history = fully repaid this bank: 2 (3.3/0.9)
##     :   credit_history = repaid:
##     :   :...existing_credits > 1: 1 (3.8)
##     :       existing_credits <= 1:
##     :       :...personal_status = divorced male: 1 (2.9)
##     :           personal_status = married male: 2 (6.1/2.4)
##     :           personal_status = single male:
##     :           :...amount <= 5848: 1 (13/2.9)
##     :               :   amount > 5848: 2 (7.5)
```

```
##      :               personal_status = female:
##      :               :...installment_plan = stores: 1 (0)
##      :                   installment_plan = bank: 2 (3)
##      :                   installment_plan = none:
##      :                   :...installment_rate <= 3: 1 (6.2)
##      :                       installment_rate > 3: 2 (10.2/3.7)
##      savings_balance = < 100 DM:
##      :...months_loan_duration > 22:
##          :...credit_history = delayed: 2 (17.9/1.5)
##          :   credit_history in {critical,fully repaid,fully repaid this bank,
##          :   :                   repaid}:
##          :   :...housing = rent: 2 (31.2/3.2)
##          :       housing = for free:
##          :       :...months_loan_duration <= 42: 1 (15.9/2.3)
##          :       :   months_loan_duration > 42: 2 (9/1.3)
##          :       housing = own:
##          :       :...property in {real estate,unknown/none}: 2 (31.8/6.5)
##          :           property = building society savings:
##          :           :...amount <= 4796: 1 (20.4/3.6)
##          :           :   amount > 4796: 2 (14/0.8)
##          :           property = other:
##          :           :...other_debtors = co-applicant: 1 (6.3/2.3)
##          :               other_debtors in {guarantor,none}: 2 (37.8/11.5)
##          months_loan_duration <= 22:
##          :...purpose in {business,domestic appliances,furniture,others,
##          :               retraining}: 1 (80.9/31.3)
##             purpose in {car (used),education,repairs}: 2 (27.3/6.3)
##             purpose = radio/tv:
##             :...other_debtors in {co-applicant,guarantor}: 1 (8.8)
##             :   other_debtors = none:
##             :   :...housing in {for free,rent}: 2 (8.3/1.3)
##             :       housing = own:
##             :       :...property in {building society savings,
##             :       :               unknown/none}: 1 (3.9)
##             :           property = other:
##             :           :...checking_balance = < 0 DM: 1 (2.5)
##             :           :   checking_balance = 1 - 200 DM: 2 (12.5/1.9)
##             :           property = real estate:
##             :           :...checking_balance = < 0 DM: 2 (14.1/5.2)
##             :               checking_balance = 1 - 200 DM: 1 (4.3)
##             purpose = car (new):
##             :...residence_history <= 1: 2 (5.3)
##                 residence_history > 1:
##                 :...installment_plan = stores: 1 (0)
##                     installment_plan = bank: 2 (11.7/2.7)
##                     installment_plan = none:
##                     :...personal_status = divorced male: 2 (2.1/0.2)
##                         personal_status in {female,married male}: 1 (14.7/4.6)
##                         personal_status = single male:
##                         :...property = real estate: 1 (9.6)
##                             property in {building society savings,other,
##                             :               unknown/none}:
##                             :...months_loan_duration <= 9: 2 (5)
##                                 months_loan_duration > 9: 1 (10.9/2.3)
```

```
##
## -----  Trial 26:  -----
##
## Decision tree:
##
## checking_balance in {< 0 DM,1 - 200 DM}:
## :...housing = for free:
## :   :...installment_plan = bank: 1 (12/3.2)
## :   :   installment_plan in {none,stores}: 2 (57.5/21.2)
## :   housing = rent:
## :   :...credit_history = delayed: 1 (8/0.7)
## :   :   credit_history in {critical,fully repaid,fully repaid this bank,repaid}:
## :   :   :...employment_length in {> 7 yrs,1 - 4 yrs}: 2 (48/13.6)
## :   :       employment_length = unemployed: 1 (2.5)
## :   :       employment_length = 4 - 7 yrs:
## :   :       :...checking_balance = < 0 DM: 2 (11.9/3)
## :   :       :   checking_balance = 1 - 200 DM: 1 (6.4)
## :   :       employment_length = 0 - 1 yrs:
## :   :       :...months_loan_duration > 21: 2 (13.2)
## :   :           months_loan_duration <= 21:
## :   :           :...age <= 28: 2 (17.9/4.6)
## :   :               age > 28: 1 (3.3)
## :   housing = own:
## :   :...property = unknown/none: 2 (28.2/5.7)
## :       property in {building society savings,other,real estate}:
## :       :...residence_history > 3:
## :           :...employment_length in {> 7 yrs,1 - 4 yrs,4 - 7 yrs,
## :           :   :                     unemployed}: 1 (92.4/27.3)
## :           :   employment_length = 0 - 1 yrs: 2 (10.4/3.1)
## :           residence_history <= 3:
## :           :...purpose in {business,car (used),domestic appliances,education,
## :               :             retraining}: 1 (49.3/12.4)
## :               purpose in {others,repairs}: 2 (18/6.7)
## :               purpose = car (new):
## :               :...savings_balance in {> 1000 DM,501 - 1000 DM,
## :               :   :                   unknown}: 1 (13.3/4.4)
## :               :   savings_balance = 101 - 500 DM: 2 (13.2/6.5)
## :               :   savings_balance = < 100 DM:
## :               :   :...months_loan_duration <= 40: 2 (40.5/10.8)
## :               :       months_loan_duration > 40: 1 (2.3)
## :               purpose = furniture:
## :               :...other_debtors = guarantor: 1 (4.9)
## :               :   other_debtors in {co-applicant,none}:
## :               :   :...savings_balance = > 1000 DM: 1 (2.3)
## :               :       savings_balance in {101 - 500 DM,501 - 1000 DM,
## :               :       :                   unknown}: 2 (5.5/1.7)
## :               :       savings_balance = < 100 DM:
## :               :       :...personal_status in {divorced male,
## :               :           :                   married male}: 1 (8.8/2.2)
## :               :           personal_status in {female,
## :               :                               single male}: 2 (36.3/9.6)
## :               purpose = radio/tv:
## :               :...age <= 25:
## :                   :...residence_history <= 2: 2 (23/3)
```

```
## :                        :    residence_history > 2: 1 (2.1)
## :                   age > 25:
## :                        :...residence_history > 2: 2 (14.3/5.2)
## :                        residence_history <= 2:
## :                        :...months_loan_duration <= 30: 1 (25.9/5.7)
## :                            months_loan_duration > 30: 2 (6.1/1.8)
## checking_balance in {> 200 DM,unknown}:
## :...employment_length in {0 - 1 yrs,unemployed}:
##     :...amount > 6681: 2 (11.3)
##     :    amount <= 6681:
##     :    :...other_debtors = co-applicant: 2 (4.8/1)
##     :        other_debtors = guarantor: 1 (1.5)
##     :        other_debtors = none:
##     :        :...amount <= 1333: 1 (10.3)
##     :            amount > 1333:
##     :            :...savings_balance in {> 1000 DM,101 - 500 DM,501 - 1000 DM,
##     :            :                       unknown}: 1 (10.7/2.5)
##     :            savings_balance = < 100 DM:
##     :            :...installment_plan = bank: 1 (4.5/1)
##     :                installment_plan = stores: 2 (4.8/1.7)
##     :                installment_plan = none:
##     :                :...employment_length = unemployed: 1 (1.8)
##     :                    employment_length = 0 - 1 yrs:
##     :                    :...months_loan_duration <= 22: 2 (17.1/2.4)
##     :                        months_loan_duration > 22: 1 (2.8)
##     employment_length in {> 7 yrs,1 - 4 yrs,4 - 7 yrs}:
##     :...months_loan_duration <= 8: 1 (19.5)
##         months_loan_duration > 8:
##         :...installment_plan = stores: 1 (15.9/4.2)
##             installment_plan = bank:
##             :...age > 44: 1 (8.9)
##             :    age <= 44:
##             :    :...age > 36: 2 (9.4)
##             :        age <= 36:
##             :        :...housing = for free: 1 (1.1)
##             :            housing = rent: 2 (2.6)
##             :            housing = own:
##             :            :...checking_balance = > 200 DM: 1 (4)
##             :                checking_balance = unknown:
##             :                :...property in {real estate,
##             :                :               unknown/none}: 1 (3.9)
##             :                property in {building society savings,other}:
##             :                :...months_loan_duration <= 27: 2 (12/2.7)
##             :                    months_loan_duration > 27: 1 (3.5)
##             installment_plan = none:
##             :...credit_history in {critical,fully repaid,
##                     :             fully repaid this bank,
##                     :             repaid}: 1 (139.9/36.8)
##                 credit_history = delayed:
##                 :...installment_rate <= 3: 1 (6.4)
##                     installment_rate > 3:
##                     :...amount <= 1525: 1 (4.2)
##                         amount > 1525:
##                         :...existing_credits <= 1: 2 (4.5)
```

```
##                                existing_credits > 1:
##                                :...personal_status in {divorced male,
##                                :                       married male}: 2 (0)
##                                    personal_status = female: 1 (2.1)
##                                    personal_status = single male:
##                                    :...amount <= 2442: 1 (8.3/2.8)
##                                        amount > 2442: 2 (6.5)
##
## -----  Trial 27:  -----
##
## Decision tree:
##
## credit_history = fully repaid:
## :...personal_status = married male: 2 (0)
## :   personal_status = divorced male: 1 (2.9)
## :   personal_status in {female,single male}:
## :   :...residence_history <= 1: 1 (7.7/2)
## :       residence_history > 1: 2 (28.9/6.3)
## credit_history = fully repaid this bank:
## :...other_debtors = co-applicant: 1 (3.4)
## :   other_debtors in {guarantor,none}:
## :   :...age <= 23: 1 (5.8)
## :       age > 23: 2 (37.9/9.6)
## credit_history = critical:
## :...checking_balance = unknown: 1 (71.5/17.3)
## :   checking_balance = > 200 DM:
## :   :...age <= 42: 2 (12/3.9)
## :   :   age > 42: 1 (7.4)
## :   checking_balance = < 0 DM:
## :   :...personal_status = divorced male: 2 (3.2/0.3)
## :   :   personal_status in {married male,single male}: 1 (45.1/11.8)
## :   :   personal_status = female:
## :   :   :...amount <= 1113: 1 (6.5)
## :   :       amount > 1113: 2 (15.7/4.4)
## :   checking_balance = 1 - 200 DM:
## :   :...residence_history <= 1: 1 (6.9)
## :       residence_history > 1:
## :       :...housing in {for free,rent}: 1 (10.4/1.2)
## :           housing = own:
## :           :...months_loan_duration <= 15: 1 (12.9/2.8)
## :               months_loan_duration > 15: 2 (36/10.6)
## credit_history = delayed:
## :...savings_balance = > 1000 DM: 2 (6.2/0.9)
## :   savings_balance in {501 - 1000 DM,unknown}: 1 (11.1)
## :   savings_balance = 101 - 500 DM:
## :   :...existing_credits <= 3: 1 (14.7/1.8)
## :   :   existing_credits > 3: 2 (2.3)
## :   savings_balance = < 100 DM:
## :   :...months_loan_duration <= 16: 1 (12.8/2.1)
## :       months_loan_duration > 16:
## :       :...checking_balance in {< 0 DM,> 200 DM}: 2 (10.3)
## :           checking_balance in {1 - 200 DM,unknown}:
## :           :...housing in {for free,rent}: 1 (6.8/2.6)
## :               housing = own:
```

```
## :                      :...purpose in {business,car (new),domestic appliances,
## :                      :                  education,furniture,retraining}: 2 (16.7/1.3)
## :                      purpose in {car (used),others,radio/tv,
## :                                  repairs}: 1 (10.6/2)
## credit_history = repaid:
## :...other_debtors = co-applicant:
##     :...months_loan_duration <= 15: 1 (8.2/0.7)
##     :   months_loan_duration > 15: 2 (18.5/5.9)
##     other_debtors = guarantor:
##     :...savings_balance in {< 100 DM,> 1000 DM,101 - 500 DM,
##     :   :                      501 - 1000 DM}: 1 (22.6/3.6)
##     :   savings_balance = unknown: 2 (4)
##     other_debtors = none:
##     :...amount > 8133:
##         :...months_loan_duration <= 36: 2 (19.5/0.1)
##         :   months_loan_duration > 36: 1 (7.2/2.5)
##         amount <= 8133:
##         :...months_loan_duration <= 7:
##             :...amount <= 4020: 1 (24.1/0.8)
##             :   amount > 4020: 2 (2.6)
##             months_loan_duration > 7:
##             :...residence_history <= 1:
##                 :...installment_rate > 2: 1 (42.2/8.1)
##                 :   installment_rate <= 2:
##                 :   :...existing_credits > 1: 2 (3.6)
##                 :       existing_credits <= 1:
##                 :       :...personal_status in {divorced male,married male,
##                 :       :                         single male}: 2 (15.7/4.5)
##                 :           personal_status = female: 1 (4.9)
##                 residence_history > 1:
##                 :...months_loan_duration > 40: 2 (16.6/1.7)
##                     months_loan_duration <= 40:
##                     :...personal_status in {divorced male,
##                     :                        married male}: 1 (45.5/14.5)
##                         personal_status = single male:
##                         :...employment_length in {0 - 1 yrs,
##                         :   :                        unemployed}: 1 (16.4/3.5)
##                         :   employment_length = 4 - 7 yrs:
##                         :   :...age <= 23: 2 (3)
##                         :   :   age > 23: 1 (17.8/3)
##                         :   employment_length = > 7 yrs:
##                         :   :...existing_credits > 2: 1 (2.5)
##                         :   :   existing_credits <= 2:
##                         :   :   :...age <= 30: 1 (5.5)
##                         :   :       age > 30: 2 (40.5/14.5)
##                         :   employment_length = 1 - 4 yrs:
##                         :   :...existing_credits > 2: 2 (3.5)
##                         :       existing_credits <= 2: [S1]
##                         personal_status = female:
##                         :...age > 54: 1 (9.3)
##                             age <= 54:
##                             :...existing_credits > 1: 2 (5.5)
##                                 existing_credits <= 1:
##                                 :...amount <= 1382: 2 (45.4/9.1)
```

```
##                                                  amount > 1382: [S2]
##
## SubTree [S1]
##
## savings_balance in {> 1000 DM,101 - 500 DM,unknown}: 1 (6)
## savings_balance = 501 - 1000 DM: 2 (2.9/0.3)
## savings_balance = < 100 DM:
## :...installment_rate <= 3:
##     :...age <= 22: 2 (4.3)
##     :   age > 22: 1 (18.1/2.7)
##     installment_rate > 3:
##     :...installment_plan = bank: 1 (2.4)
##         installment_plan in {none,stores}: 2 (18.4/2.7)
##
## SubTree [S2]
##
## savings_balance in {> 1000 DM,101 - 500 DM,unknown}: 1 (17/3.3)
## savings_balance = 501 - 1000 DM: 2 (2.8/0.5)
## savings_balance = < 100 DM:
## :...property = unknown/none: 1 (0)
##     property in {building society savings,real estate}:
##     :...months_loan_duration <= 13: 1 (2.3)
##     :   months_loan_duration > 13: 2 (16.5/2.6)
##     property = other:
##     :...months_loan_duration <= 30: 1 (16.5/1.5)
##         months_loan_duration > 30: 2 (2.8)
##
## -----  Trial 28:  -----
##
## Decision tree:
##
## checking_balance in {< 0 DM,1 - 200 DM}:
## :...installment_rate <= 2:
## :   :...housing = for free: 1 (24.4/5.4)
## :   :   housing = own:
## :   :   :...age <= 26: 2 (46.6/14.9)
## :   :   :   age > 26:
## :   :   :   :...age <= 28: 1 (13.5)
## :   :   :       age > 28:
## :   :   :       :...installment_plan = stores: 2 (4.7)
## :   :   :           installment_plan = bank:
## :   :   :           :...amount <= 6403: 1 (13.8)
## :   :   :           :   amount > 6403: 2 (3.2)
## :   :   :           installment_plan = none:
## :   :   :           :...existing_credits > 2: 2 (3.5/0.1)
## :   :   :               existing_credits <= 2: [S1]
## :   :   housing = rent:
## :   :   :...residence_history <= 1: 2 (3)
## :   :       residence_history > 1:
## :   :       :...savings_balance in {> 1000 DM,501 - 1000 DM,
## :   :       :                       unknown}: 1 (11.6)
## :   :           savings_balance in {< 100 DM,101 - 500 DM}:
## :   :           :...residence_history <= 3: 1 (7.8/0.8)
## :   :               residence_history > 3:
```

```
## :    :                      :...property = unknown/none: 1 (0)
## :    :                         property = building society savings: 2 (2.6)
## :    :                         property in {other,real estate}:
## :    :                         :...age <= 21: 2 (4.3)
## :    :                            age > 21:
## :    :                            :...amount > 6887: 2 (3.2)
## :    :                                amount <= 6887:
## :    :                                :...months_loan_duration <= 9: 2 (2.3)
## :    :                                    months_loan_duration > 9: 1 (15.8/1.6)
## :    installment_rate > 2:
## :    :...credit_history in {delayed,fully repaid}: 2 (39.3/10.3)
## :        credit_history = fully repaid this bank:
## :        :...personal_status in {divorced male,female}: 2 (5.4)
## :        :   personal_status = married male: 1 (2.3)
## :        :   personal_status = single male:
## :        :   :...checking_balance = < 0 DM: 2 (12.3/2.7)
## :        :       checking_balance = 1 - 200 DM: 1 (5.7)
## :        credit_history = repaid:
## :        :...savings_balance in {> 1000 DM,501 - 1000 DM}: 1 (12.1/3.9)
## :        :   savings_balance = 101 - 500 DM: 2 (20.6/6.3)
## :        :   savings_balance = unknown:
## :        :   :...housing = for free: 1 (6.1/0.5)
## :        :   :   housing = rent: 2 (3.2)
## :        :   :   housing = own:
## :        :   :   :...existing_credits <= 1: 2 (14.8/5.7)
## :        :   :       existing_credits > 1: 1 (3.1)
## :        :   savings_balance = < 100 DM:
## :        :   :...purpose in {business,domestic appliances,
## :        :   :                 retraining}: 2 (11.3/3.4)
## :        :       purpose in {car (used),education,others,repairs}: 1 (29.9/12.5)
## :        :       purpose = car (new):
## :        :       :...amount <= 1204: 1 (8.7/1.6)
## :        :       :   amount > 1204: 2 (25.6/1.6)
## :        :       purpose = furniture:
## :        :       :...other_debtors = co-applicant: 1 (2.5)
## :        :       :   other_debtors in {guarantor,none}: 2 (27.4/11.8)
## :        :       purpose = radio/tv:
## :        :       :...other_debtors in {co-applicant,guarantor}: 1 (3.4)
## :        :           other_debtors = none:
## :        :           :...existing_credits > 1: 2 (4.5/0.6)
## :        :               existing_credits <= 1:
## :        :               :...installment_plan in {bank,none}: 1 (34.3/11.4)
## :        :                   installment_plan = stores: 2 (5.1/1)
## :        credit_history = critical:
## :        :...existing_credits > 2: 1 (7.3)
## :            existing_credits <= 2:
## :            :...employment_length = 4 - 7 yrs: 1 (9)
## :                employment_length in {> 7 yrs,0 - 1 yrs,1 - 4 yrs,unemployed}:
## :                :...property = unknown/none: 2 (11.4/0.6)
## :                    property in {building society savings,other,real estate}:
## :                    :...savings_balance in {> 1000 DM,101 - 500 DM,
## :                    :                        unknown}: 1 (9.3)
## :                        savings_balance = 501 - 1000 DM: 2 (2.4/0.7)
## :                        savings_balance = < 100 DM:
```

```
## :                                    :...personal_status in {divorced male,
## :                                    :                    married male}: 2 (8/1)
## :                                personal_status = female: 1 (8.4/3.3)
## :                                personal_status = single male:
## :                                :...employment_length in {1 - 4 yrs,
## :                                :                    unemployed}: 1 (11.7)
## :                                employment_length in {> 7 yrs,0 - 1 yrs}: [S2]
## checking_balance in {> 200 DM,unknown}:
## :...employment_length in {> 7 yrs,4 - 7 yrs}: 1 (125.3/29.4)
##     employment_length = unemployed:
##     :...installment_rate <= 2: 1 (3.1)
##     :   installment_rate > 2: 2 (11.8/2.8)
##     employment_length = 0 - 1 yrs:
##     :...other_debtors = co-applicant: 2 (2.1)
##     :   other_debtors = guarantor: 1 (1)
##     :   other_debtors = none:
##     :   :...amount > 4594: 2 (12.3/1.8)
##     :       amount <= 4594:
##     :       :...purpose in {business,car (new),car (used),domestic appliances,
##     :       :               education,furniture,others,radio/tv,
##     :       :               retraining}: 1 (31/5.1)
##     :           purpose = repairs: 2 (2.5)
##     employment_length = 1 - 4 yrs:
##     :...months_loan_duration <= 7: 1 (10.4)
##         months_loan_duration > 7:
##         :...installment_rate <= 1: 1 (9.9/1)
##             installment_rate > 1:
##             :...installment_plan in {bank,stores}: 2 (19.7/5.3)
##                 installment_plan = none:
##                 :...other_debtors = co-applicant: 1 (1.1)
##                     other_debtors = guarantor: 2 (4.7/1.5)
##                     other_debtors = none:
##                     :...purpose in {car (new),car (used),domestic appliances,
##                     :               others,repairs,retraining}: 1 (18)
##                         purpose in {business,education,furniture,radio/tv}:
##                         :...age <= 25: 1 (7.9)
##                             age > 25:
##                             :...age <= 30:
##                                 :...installment_rate <= 2: 1 (2.8)
##                                 :   installment_rate > 2: 2 (23.3/2.9)
##                                 age > 30:
##                                 :...existing_credits <= 2: 1 (21.3/5.6)
##                                     existing_credits > 2: 2 (2.8)
##
## SubTree [S1]
##
## credit_history in {delayed,fully repaid}: 1 (9.3)
## credit_history = fully repaid this bank: 2 (1.2)
## credit_history = critical:
## :...checking_balance = < 0 DM: 1 (3.6)
## :   checking_balance = 1 - 200 DM: 2 (11.2/3)
## credit_history = repaid:
## :...employment_length in {> 7 yrs,4 - 7 yrs}: 2 (11.8/3.1)
##     employment_length in {0 - 1 yrs,1 - 4 yrs,unemployed}: 1 (24.2/5.9)
```

```
##
## SubTree [S2]
##
## property in {building society savings,other}: 2 (16.1/2)
## property = real estate: 1 (6.2/0.4)
##
## -----  Trial 29:  -----
##
## Decision tree:
##
## savings_balance in {501 - 1000 DM,unknown}:
## :...other_debtors = co-applicant: 1 (8)
## :    other_debtors = guarantor: 2 (3.7/1.1)
## :    other_debtors = none:
## :    :...credit_history = delayed: 1 (13.1)
## :        credit_history in {critical,fully repaid,fully repaid this bank,repaid}:
## :        :...months_loan_duration <= 11: 1 (23.7/1.4)
## :            months_loan_duration > 11:
## :            :...installment_plan = stores: 1 (7.4/0.6)
## :                installment_plan = bank:
## :                :...personal_status = female: 2 (9.5)
## :                :   personal_status in {divorced male,married male,single male}:
## :                :   :...residence_history <= 2: 2 (9.2/1.6)
## :                :        residence_history > 2: 1 (11.1)
## :                installment_plan = none:
## :                :...checking_balance in {< 0 DM,> 200 DM}: 2 (30.7/10.1)
## :                    checking_balance in {1 - 200 DM,unknown}:
## :                    :...employment_length in {> 7 yrs,4 - 7 yrs}: 1 (27.8)
## :                        employment_length in {0 - 1 yrs,1 - 4 yrs,unemployed}:
## :                        :...months_loan_duration > 28: 1 (9.9)
## :                            months_loan_duration <= 28:
## :                            :...checking_balance = unknown: 1 (17.5/4.9)
## :                                checking_balance = 1 - 200 DM:
## :                                :...installment_rate <= 1: 1 (3.2)
## :                                    installment_rate > 1: 2 (15.8/3.4)
## savings_balance in {< 100 DM,> 1000 DM,101 - 500 DM}:
## :...months_loan_duration > 47: 2 (36.5/8)
##     months_loan_duration <= 47:
##     :...purpose in {domestic appliances,others,retraining}: 1 (18.5/4.1)
##         purpose = education: 2 (40.6/11)
##         purpose = business:
##         :...age <= 41: 1 (50.9/14.1)
##         :   age > 41: 2 (15.3/3.1)
##         purpose = repairs:
##         :...property in {building society savings,other,
##         :   :              real estate}: 1 (20.6/6.4)
##         :   property = unknown/none: 2 (10.6)
##         purpose = car (used):
##         :...amount > 11054: 2 (4.1)
##         :   amount <= 11054:
##         :   :...age <= 68: 1 (38.8/5.9)
##         :       age > 68: 2 (2.2)
##         purpose = car (new):
##         :...installment_plan = stores: 2 (5.4/1.6)
```

```
##              :    installment_plan = bank:
##              :    :...savings_balance = < 100 DM: 2 (23.1/2.8)
##              :    :   savings_balance in {> 1000 DM,101 - 500 DM}: 1 (7.4/0.5)
##              :    installment_plan = none:
##              :    :...other_debtors = guarantor: 1 (5.5)
##              :        other_debtors in {co-applicant,none}:
##              :        :...credit_history in {fully repaid,
##              :        :                     fully repaid this bank}: 2 (5.3)
##              :            credit_history in {critical,delayed,repaid}:
##              :            :...checking_balance in {> 200 DM,unknown}: 1 (25.2/7.7)
##              :                checking_balance = 1 - 200 DM:
##              :                :...residence_history <= 3: 1 (18.9/2.8)
##              :                :   residence_history > 3: 2 (12.3/5.1)
##              :                checking_balance = < 0 DM:
##              :                :...savings_balance in {> 1000 DM,
##              :                :                       101 - 500 DM}: 1 (3.9)
##              :                    savings_balance = < 100 DM:
##              :                    :...installment_rate <= 2: 1 (15.7/5.3)
##              :                        installment_rate > 2: 2 (34.4/10)
##          purpose = furniture:
##          :...savings_balance = > 1000 DM: 1 (7.2)
##          :   savings_balance in {< 100 DM,101 - 500 DM}:
##          :   :...installment_plan = stores: 1 (5.4)
##          :       installment_plan in {bank,none}:
##          :       :...housing = for free: 1 (11.7/1.1)
##          :           housing in {own,rent}:
##          :           :...credit_history in {delayed,
##          :           :                     fully repaid this bank}: 2 (9.1/1.4)
##          :               credit_history = fully repaid: 1 (6.5/2.1)
##          :               credit_history = critical:
##          :               :...housing = rent: 2 (12.5/4.4)
##          :               :   housing = own:
##          :               :   :...age <= 47: 1 (17.1/2)
##          :               :       age > 47: 2 (3.5)
##          :               credit_history = repaid:
##          :               :...property = real estate: 1 (25.1/9.8)
##          :                   property = unknown/none: 2 (0.5)
##          :                   property = building society savings:
##          :                   :...amount <= 4380: 1 (26.6/4.3)
##          :                   :   amount > 4380: 2 (3.5)
##          :                   property = other:
##          :                   :...other_debtors in {co-applicant,
##          :                   :                     guarantor}: 2 (4)
##          :                       other_debtors = none:
##          :                       :...housing = rent: 1 (5.3/1.7)
##          :                           housing = own:
##          :                           :...months_loan_duration <= 15: 1 (7.3/2.2)
##          :                               months_loan_duration > 15: 2 (9.8/0.4)
##          purpose = radio/tv:
##          :...credit_history in {critical,delayed,
##          :                      fully repaid this bank}: 1 (47.2/14.7)
##              credit_history = fully repaid: 2 (3.8)
##              credit_history = repaid:
##              :...other_debtors = guarantor: 1 (6.5)
```

```
##                        other_debtors in {co-applicant,none}:
##                        :...age <= 22:
##                            :...employment_length in {> 7 yrs,1 - 4 yrs}: 1 (4.3/1)
##                            :   employment_length in {0 - 1 yrs,4 - 7 yrs,
##                            :                           unemployed}: 2 (15.5)
##                            age > 22:
##                            :...residence_history <= 1: 1 (8.9/0.8)
##                                residence_history > 1:
##                                :...months_loan_duration <= 13: 1 (23.6/3.8)
##                                    months_loan_duration > 13:
##                                    :...existing_credits > 1: 2 (5.9)
##                                        existing_credits <= 1:
##                                        :...checking_balance = unknown: 1 (6.4)
##                                            checking_balance in {< 0 DM,> 200 DM,
##                                            :                           1 - 200 DM}:
##                                            :...age <= 42: 2 (32.6/8.3)
##                                                age > 42: 1 (4.4/0.4)
##
##
## Evaluation on training data (900 cases):
##
## Trial        Decision Tree
## -----        ----------------
##    Size        Errors
##
##    0     83  100(11.1%)
##    1     55  184(20.4%)
##    2     70  142(15.8%)
##    3     53  146(16.2%)
##    4     36  183(20.3%)
##    5     68  159(17.7%)
##    6     66  156(17.3%)
##    7     64  180(20.0%)
##    8     72  145(16.1%)
##    9     68  152(16.9%)
##   10     59  147(16.3%)
##   11     61  229(25.4%)
##   12     52  191(21.2%)
##   13     76  153(17.0%)
##   14     58  149(16.6%)
##   15     54  151(16.8%)
##   16     79  161(17.9%)
##   17     77  138(15.3%)
##   18     70  177(19.7%)
##   19     64  205(22.8%)
##   20     69  144(16.0%)
##   21     60  155(17.2%)
##   22     57  165(18.3%)
##   23     67  163(18.1%)
##   24     84  144(16.0%)
##   25     57  174(19.3%)
##   26     56  185(20.6%)
##   27     62  181(20.1%)
##   28     71  156(17.3%)
```

```
##    29     62   152(16.9%)
## boost                1( 0.1%)    <<
##
##
##      (a)    (b)      <-classified as
##     ----   ----
##      633             (a): class 1
##        1    266      (b): class 2
##
##
##   Attribute usage:
##
##   100.00% checking_balance
##   100.00% months_loan_duration
##   100.00% credit_history
##   100.00% purpose
##   100.00% savings_balance
##   100.00% employment_length
##   100.00% other_debtors
##   100.00% installment_plan
##    99.78% amount
##    98.89% age
##    97.56% residence_history
##    97.33% property
##    96.89% installment_rate
##    95.56% personal_status
##    92.89% housing
##    89.89% existing_credits
##
##
## Time: 0.1 secs
```

Testing boost on testing data

```
credit_boost_pred10 <- predict(credit_boost10, testing)
CrossTable(testing$default, credit_boost_pred10, prop.chisq = FALSE, prop.c = FALSE, prop.r = FALSE, dnm
```

```
##
##
##     Cell Contents
## |-------------------------|
## |                       N |
## |           N / Table Total |
## |-------------------------|
##
##
## Total Observations in Table:   100
##
##
##                  | predicted default
## actual default  |          1 |          2 | Row Total |
## ---------------|-----------|-----------|-----------|
##              1 |         60 |          7 |         67 |
##                |      0.600 |      0.070 |            |
## ---------------|-----------|-----------|-----------|
```

```
##               2 |        16 |        17 |        33 |
##                 |     0.160 |     0.170 |           |
## ---------------|-----------|-----------|-----------|
##   Column Total |        76 |        24 |       100 |
## ---------------|-----------|-----------|-----------|
##
##
```

#with 30 trials we can observe that our model has improved to 23%

We can observe that even though the model improves, it still does make losses to banks. 23% is quite high.

Giving a loan out to an applicant who is likely to default can be an expensive mistake. One solution to reduce the number of false negatives may be to reject a larger number of borderline applicants, under the assumption that the interest the bank would earn from a risky loan is far outweighed by the massive loss it would incur if the money is not paid back at all.

The C5.0 algorithm allows us to assign a penalty to different types of errors, in order to discourage a tree from making more costly mistakes. The penalties are designated in a cost matrix, which specifies how much costlier each error is, relative to any other prediction. To begin constructing the cost matrix, we need to start by specifying the dimensions. Since the predicted and actual values can both take two values, yes or no, we need to describe a 2 x 2 matrix, using a list of two vectors, each with two values. At the same time, we'll also name the matrix dimensions to avoid confusion later on-

```
matrix_dimensions <- list(c("1", "2"), c("1", "2"))
names(matrix_dimensions) <- c("predicted", "actual")
```

Next, we need to assign the penalty for the various types of errors by supplying four values to fill the matrix. Since R lls a matrix by filling columns one by one from top to bottom, we need to supply the values in a speci c order: • Predicted no, actual no • Predicted yes, actual no • Predicted no, actual yes • Predicted yes, actual yes

```
error_cost <- matrix(c(0, 1, 4, 0), nrow = 2, dimnames = matrix_dimensions)
```

As defined by this matrix, there is no cost assigned when the algorithm classifies a no or yes correctly, but a false negative has a cost of 4 versus a false positive's cost of 1. To see how this impacts classification, let's apply it to our decision tree using the costs parameter of the C5.0() function. We'll otherwise use the same steps as we did earlier:

```
credit_cost <- C5.0(training[-17], training$default, costs = error_cost)
credit_cost_pred <- predict(credit_cost, testing)
CrossTable(testing$default, credit_cost_pred, prop.chisq = FALSE, prop.c = FALSE, prop.r = FALSE, dnn =
```

```
##
##
##    Cell Contents
## |-------------------------|
## |                       N |
## |         N / Table Total |
## |-------------------------|
##
##
## Total Observations in Table:  100
##
##
##                | predicted default
## actual default |         1 |         2 | Row Total |
## ---------------|-----------|-----------|-----------|
```

```
##               1 |         32 |         35 |         67 |
##                 |      0.320 |      0.350 |            |
## --------------|-----------|-----------|-----------|
##               2 |          7 |         26 |         33 |
##                 |      0.070 |      0.260 |            |
## --------------|-----------|-----------|-----------|
##    Column Total |         39 |         61 |        100 |
## --------------|-----------|-----------|-----------|
##
##
```

Conclusion: Even though the final model makes more mistakes, we will prefer this as it is better to not give loans to people who will default more likely at the trade off cost of making mistakes while rejecting giving loan to people who would more likely not default.