

# EE583 Pattern Recognition HW5

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January 3, 2022

## 1 Question 1

3 different experiments are conducted. In each experiment, ten models are individually used to calculate the accuracy, or equivalently misclassification loss.

### 1.1 Default settings

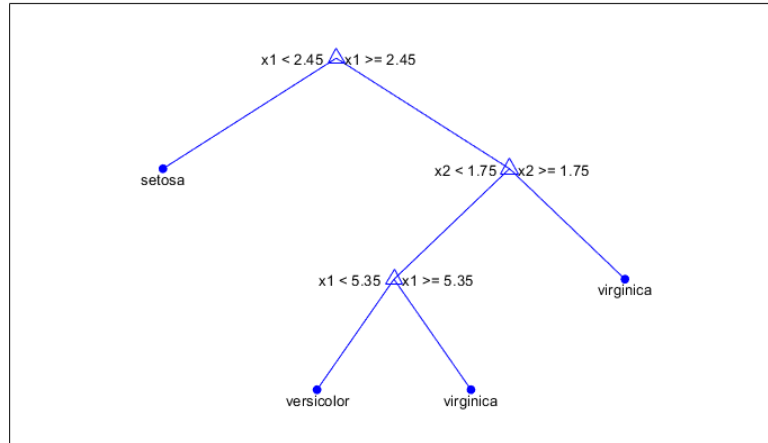


Figure 1: Visualization of the first tree

This 3 split tree resulted in a loss of 0.0267.

### 1.2 Maximum number of Splits Restriction

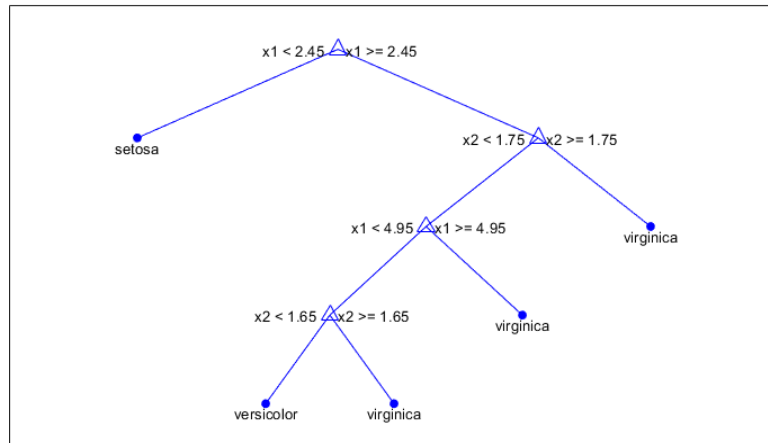


Figure 2: Visualization of the second tree

For this experiment the resultant number of splits was higher than the first one. Therefore, it resulted in less misclassification loss of 0.0240.

### 1.3 Maximum number of Splits Restriction

Changing the split criterion from Gini's diversity index to deviance resulted in the improvement of the accuracy.

## 2 Question 2

### 2.1 Single tree vs Ensemble

To observe the performance difference between a single tree and the ensemble better, the number of splits were set to 1 to decrease the classification capability of the single tree. Otherwise, even the first weak learner is able to classify the data accurate enough.

$$Accuracy_{first} = 0.64$$

$$Accuracy_{ensemble} = 0.95$$

The results reflect our expectations on the performance of the ensemble trained with Adaboost being better.

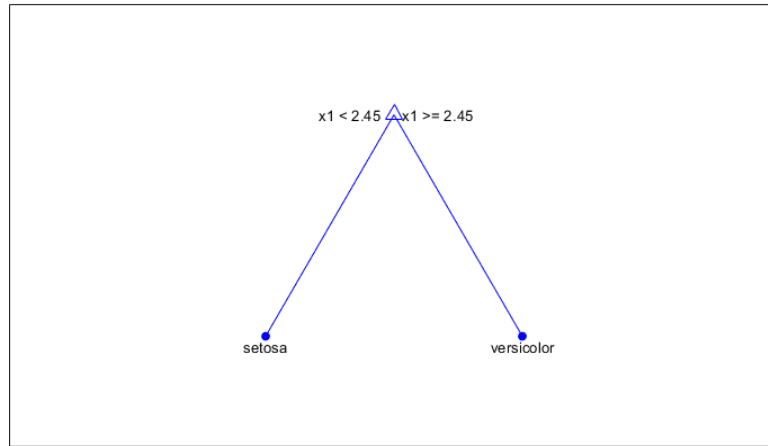


Figure 3: Visualization of the first tree

### 2.2 Learning Rate

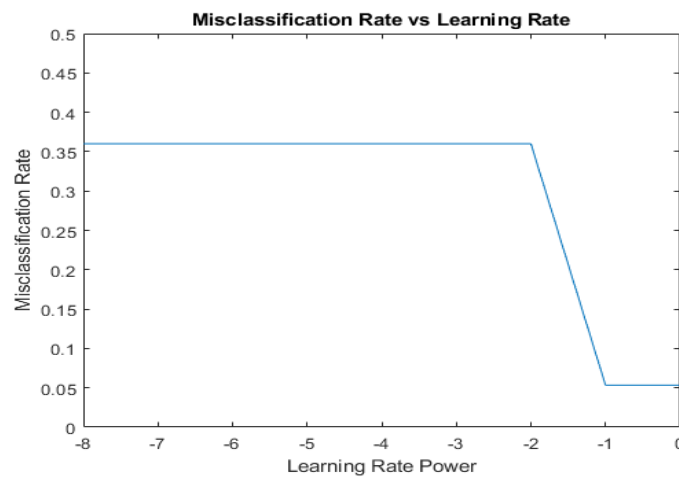


Figure 4: Learning Rate vs Misclassification

Again, the maximum number of splits is fixed among experiments, which can be seen in 5.2. Larger learning rates resulted ensemble to achieve higher accuracy, since the informative samples have more weights in the training process.

### 3 Question 3

#### 3.1 Learning Rate

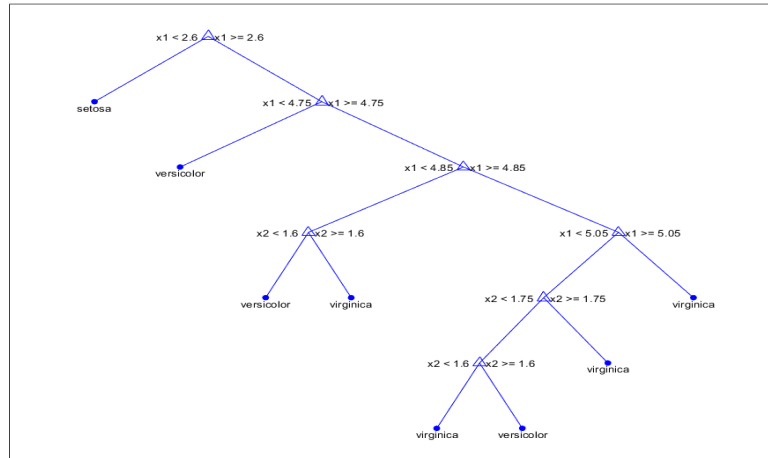


Figure 5: First Tree

The accuracy of the first tree is calculated as 0.9867 whereas the forest's is 1. We see that, with the help of the 24 remaining tree models in the treebagger object, the model was able to classify the samples correctly that are misclassified by the first tree. Hence, the classification accuracy improved.

### 4 Question 4

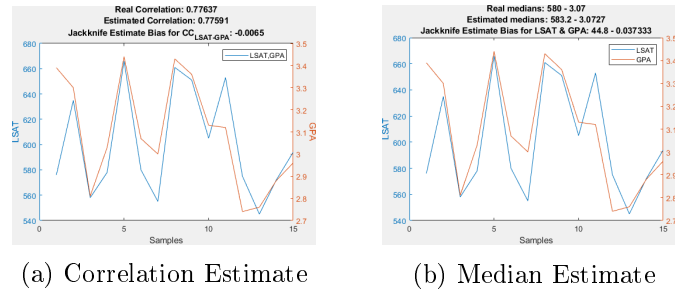



Figure 6: Jackknife estimates

The variables are plotted with respect to different axes in both Figure 6a and 6b. The estimates and the estimated bias are calculated and printed in the title. The resultant biases are respectively low when the variance of the relative variables are taken into account.

## 5 APPENDIX

The code given in this section is shared @.

### 5.1 Q1

```

1 %%
2 clear;   clc;
3 chdir('..')
4 addpath('export_fig')
5 chdir('HW5')
6 rng(101)
7 %%
8 load fisheriris.mat
9 feats = meas(:,3:4);
10 Y = species;
11 %%
12 tree_model = fitctree(feats,species,'CrossVal','on');
13 view(tree_model.Trained{1},'Mode','graph')
14 Ls = [];
15 for i = 1:10
16     model = tree_model.Trained{i};
17     preds = predict(model,feats);
18     confusion_matrix = confusionmat(species,preds);
19     accuracy = sum(diag(confusion_matrix))/sum(sum(confusion_matrix))
20     ;
21     loss = 1 - accuracy;
22     Ls(end+1) = loss;
23 end
24 mean_loss_default = mean(Ls);
25 %%
26 tree_model = fitctree(feats,species,'CrossVal','on','MaxNumSplits',7)
27 ;
28 view(tree_model.Trained{1},'Mode','graph')
29 Ls = [];
30 for i = 1:10
31     model = tree_model.Trained{i};
32     preds = predict(model,feats);
33     confusion_matrix = confusionmat(species,preds);
34     accuracy = sum(diag(confusion_matrix))/sum(sum(confusion_matrix))
35     ;
36     loss = 1 - accuracy;
37     Ls(end+1) = loss;
38 end
39 mean_loss_restricted_splits = mean(Ls);
40 %%
41 tree_model = fitctree(feats,species,'CrossVal','on','SplitCriterion','deviance');
42 view(tree_model.Trained{1},'Mode','graph')
43 Ls = [];
44 for i = 1:10

```

```
43     model = tree_model.Trained{i};
44     preds = predict(model, feats);
45     confusion_matrix = confusionmat(species, preds);
46     accuracy = sum(diag(confusion_matrix))/sum(sum(confusion_matrix))
47         ;
48     loss = 1 - accuracy;
49     Ls(end+1) = loss;
50 end
51 mean_loss_split_criterion = mean(Ls);
52 %%
53 figHandles = findall(0, 'Type', 'figure');
54 for i = 1:numel(figHandles)
55     export_fig(['Q1_', num2str(i)], '-png', figHandles(i), '-append')
56 end
57
58 hTree=findall(0, 'Tag', 'tree viewer');
59 % close(hTree)
60
61 mean_loss_default
62 mean_loss_restricted_splits
63 mean_loss_split_criterion
```

## 5.2 Q2

```

1  clc , clear ;
2  load fisheriris.mat
3  feats = meas(:,3:4);
4  Y = species;
5  rng(101)
6
7  % Cross varidation (train: 50%, test: 50%)
8  cv = cvpartition(size(feats,1), 'HoldOut', 0.5);
9  idx = cv.test;
10
11 % Separate to training and test data
12 feats_Train = feats(~idx,:);
13 feats_Test = feats(idx,:);
14 Y_Train = Y(~idx);
15 Y_Test = Y(idx);
16
17 % To amplify the difference of the classification success , the number
    of
18 % splits are restricted for a single tree to also highlight the
    adaboost
19 % success
20 t = templateTree('MaxNumSplits',1);
21 Mdl = fitcensemble(feats_Train,Y_Train,'Method','AdaBoostM2', ...
22     'Learners',t,'NumLearningCycles',25);
23 view(Mdl.Trained{1},'Mode','graph')
24 preds = predict(Mdl.Trained{1},feats_Test);
25 confusionmatrix = confusionmat(Y_Test,preds);
26 first_tree_accuracy = sum(diag(confusionmatrix))/sum(sum(
    confusionmatrix))
27 preds = predict(Mdl,feats_Test);
28 confusionmatrix = confusionmat(Y_Test,preds);
29 ensemble_tree_accuracy = sum(diag(confusionmatrix))/sum(sum(
    confusionmatrix))
30
31
32 accs = [];
33 for lr = 10.^[-8:0]
34     t = templateTree('MaxNumSplits',3);
35     Mdl = fitcensemble(feats_Train,Y_Train,'Method','AdaBoostM2', ...
36         'Learners',t,'NumLearningCycles',25, 'LearnRate',lr);
37     preds = predict(Mdl,feats_Test);
38     confusionmatrix = confusionmat(Y_Test,preds);
39     model_accuracy = sum(diag(confusionmatrix))/sum(sum(
        confusionmatrix));
40     accs(end+1) = model_accuracy;
41 end
42
43 figure
44 plot(-8:0,1-accs)

```

```
45 ylim([0 0.5])
46 title('Misclassification Rate vs Learning Rate')
47 ylabel('Misclassification Rate')
48 xlabel('Learning Rate Power')
```



### 5.3 Q3

```
1  clc , clear ;
2  load fisheriris.mat
3  feats = meas(:,3:4);
4  Y = species;
5  rng(101)
6
7  % Cross varidation (train: 50%, test: 50%)
8  cv = cvpartition(size(feats,1), 'HoldOut', 0.5);
9  idx = cv.test;
10
11 % Separate to training and test data
12 feats_Train = feats(~idx,:);
13 feats_Test = feats(idx,:);
14 Y_Train = Y(~idx);
15 Y_Test = Y(idx);
16
17 Mdl = TreeBagger(25,feats,Y, 'OOBPrediction', 'On', ...
18     'Method', 'classification', 'SampleWithReplacement', 'on');
19
20
21 view(Mdl.Trees{1}, 'Mode', 'graph')
22 preds = predict(Mdl.Trees{1},feats_Test);
23 confusionmatrix = confusionmat(Y_Test,preds);
24 first_tree_accuracy = sum(diag(confusionmatrix))/sum(sum(
    confusionmatrix))
25 preds = predict(Mdl,feats_Test);
26 confusionmatrix = confusionmat(Y_Test,preds);
27 ensemble_tree_accuracy = sum(diag(confusionmatrix))/sum(sum(
    confusionmatrix))
```

## 5.4 Q4

```

1  load lawdata
2  rhohat = corr(lsat , gpa);
3
4  %%
5  rng default; % For reproducibility
6  jackrho = jackknife(@corr, lsat , gpa);
7  meanrho = mean(jackrho);
8  yyaxis left
9  plot(lsat)
10 ylabel('LSAT')
11 hold on
12 yyaxis right
13 plot(gpa)
14 h = ylabel('GPA', 'Rotation', 270);
15 xlabel('Samples')
16 h.Position(1) = 16.5; % change horizontal position of ylabel
17 legend('LSAT', 'GPA')
18 n = length(lsat);
19 biasrho = round((n-1) * (meanrho-rhohat), 4);
20 title(['Real Correlation: ', num2str(rhohat)], ['Estimated Correlation'
        : ', num2str(meanrho)]], ['Jackknife Estimate Bias for CC_{LSAT-GPA'
        } : ', num2str(biasrho)], 'FontWeight', 'bold')
21
22
23
24 %%
25 rng default; % For reproducibility
26 jackmed = jackknife(@median, lsat);
27 meanmed_lsat = mean(jackmed);
28 n = length(lsat);
29 bias_lsat_median = (n-1) * (meanmed_lsat-median(lsat))
30
31 jackmed = jackknife(@median, gpa);
32 meanmed_gpa = mean(jackmed);
33 n = length(gpa);
34 bias_gpa_median = (n-1) * (meanmed_gpa-median(gpa))
35
36 figure
37 yyaxis left
38 hp1 = plot(lsat);
39 ylabel('LSAT')
40 hold on
41 yyaxis right
42 hp2 = plot(gpa);
43 legend([hp1, hp2], 'LSAT', 'GPA')
44 xlabel('Samples')
45 h = ylabel('GPA', 'Rotation', 270);
46 h.Position(1) = 16.5; % change horizontal position of ylabel
47

```

```
48 title ({ [ 'Real medians: ', num2str(median(lsat)), ' - ', num2str(median(  
    gpa)) ], [ 'Estimated medians: ', num2str(meanmed_lsat), ' - ', num2str(  
    meanmed_gpa) ], [ 'Jackknife Estimate Bias for LSAT & GPA: ', num2str(  
    bias_lsat_median), ' - ', num2str(bias_gpa_median) ] })  
49  
50  
51  
52 figHandles = findall(0, 'Type', 'figure');  
53  
54 for i = 1:numel(figHandles)  
55     export_fig(['Q4_', num2str(i)], '-png', figHandles(i), '-append')  
56 end  
57 close all
```