CS3481 Fundamentals of Data Science

Assignment 2

Random Forest and Naive Bayes Classifier Report

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Question A

Question A Data Generalization Parameter Setting

I generate the results with the following parameters:

- Test Size: 0.1
- Train Split Random State: 27
- Model Random State: 0
- Criterion: gini
- Max Depth: None
- Mini Samples Split: 2
- Max Features: “sqrt”

Question A Data Generalization

The following is the data I generated for Question 1, which covers the n_estimator from 1 to 200 with step of 1 and 200 to 1000 with step of 10. Their accuracy scores is also displayed as follows.

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n_estimator:  1 Accuracy Scores:  0.7419354838709677
n_estimator:  2 Accuracy Scores:  0.8064516129032258
n_estimator:  3 Accuracy Scores:  0.7741935483870968
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Question A Analysis

Analysis 1: Random Forest model with The Best Classification Performance

After generating the data above, I sorted the data record by accuracy scores, and get the random forest model corresponding to the best classification performance is when n_estimators of 115.

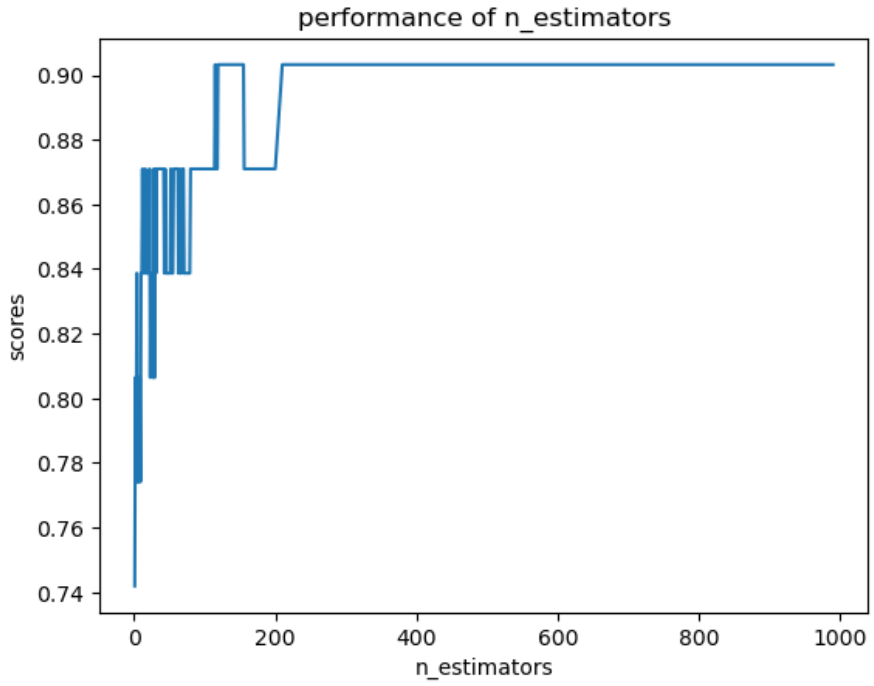
```
Max Scores:  0.9032258064516129 With n_estimators: 115
```

Analysis 2: The Performance of Models with Different n_estimators

Observations

The Variations of the Model Performance: From the below graph, the conclusion is drawn that the performance is changing a lot when the n_estimators is ranging between 1 to 200, and the model performance is steady when the n_estimators is reaching above 200.

Distribution of model accuracy： From the below graph, it's easy to find the accuracy scores of the model performance is ranging from 0.74 to. 0.904. And it finally reaches a step scores of 0.904.



Findings

- From the above figures, it's easy to find that the n_estimator parameters plays a very important role in influencing the model performance.
- Increasing the number of trees in a random forest model can improve its performance by reducing the model's variance and increasing its stability. However,

increasing the number of trees beyond a certain point may not necessarily improve the model's performance and can even lead to overfitting.

- From the above observations, in this case, it’s easy to reach a conclusion that in order to get the models with a good performance and not time-consuming, we can train the models with n_estimators ranging from 1 to 200, and choose the relatively best one. This would reduce some unnecessary computation time.

Question B

Question B Component Trees Accuracy Scores Data

From the Question A, the best classification model is found with the n_estimators of 115, which contains 115 component trees, I have put the generated accuracy scores for different component trees as below.

```
DecisionTreeClassifier(max_features='sqrt', random_state=209652396)
                        0.7419354838709677
DecisionTreeClassifier(max_features='sqrt', random_state=398764591)
                        0.7741935483870968
DecisionTreeClassifier(max_features='sqrt', random_state=924231285)
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DecisionTreeClassifier(max_features='sqrt', random_state=1478610112)
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DecisionTreeClassifier(max_features='sqrt', random_state=441365315)
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DecisionTreeClassifier(max_features='sqrt', random_state=192771779)
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DecisionTreeClassifier(max_features='sqrt', random_state=530702035)
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DecisionTreeClassifier(max_features='sqrt', random_state=626610453)
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DecisionTreeClassifier(max_features='sqrt', random_state=1650906866)
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DecisionTreeClassifier(max_features='sqrt', random_state=1879422756)
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DecisionTreeClassifier(max_features='sqrt', random_state=1277901399)
                        0.7741935483870968
DecisionTreeClassifier(max_features='sqrt', random_state=1682652230)
                        0.8064516129032258
DecisionTreeClassifier(max_features='sqrt', random_state=243580376)
                        0.7741935483870968
DecisionTreeClassifier(max_features='sqrt', random_state=1991416408)
                        0.7741935483870968
DecisionTreeClassifier(max_features='sqrt', random_state=1171049868)
                        0.7741935483870968
DecisionTreeClassifier(max_features='sqrt', random_state=1646868794)
                        0.8387096774193549
DecisionTreeClassifier(max_features='sqrt', random_state=2051556033)
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DecisionTreeClassifier(max_features='sqrt', random_state=1252949478)
                        0.9032258064516129
DecisionTreeClassifier(max_features='sqrt', random_state=1340754471)
                        0.8064516129032258
DecisionTreeClassifier(max_features='sqrt', random_state=124102743)
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DecisionTreeClassifier(max_features='sqrt', random_state=2061486254)
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DecisionTreeClassifier(max_features='sqrt', random_state=292249176)
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DecisionTreeClassifier(max_features='sqrt', random_state=1686997841)
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DecisionTreeClassifier(max_features='sqrt', random_state=1827923621)
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DecisionTreeClassifier(max_features='sqrt', random_state=1443447321)
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DecisionTreeClassifier(max_features='sqrt', random_state=305097549)
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DecisionTreeClassifier(max_features='sqrt', random_state=1449105480)
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DecisionTreeClassifier(max_features='sqrt', random_state=374217481)
                        0.6451612903225806
DecisionTreeClassifier(max_features='sqrt', random_state=636393364)
                        0.8387096774193549
DecisionTreeClassifier(max_features='sqrt', random_state=86837363)
                        0.9032258064516129
DecisionTreeClassifier(max_features='sqrt', random_state=1581585360)
                        0.7419354838709677
DecisionTreeClassifier(max_features='sqrt', random_state=1428591347)
                        0.7741935483870968
DecisionTreeClassifier(max_features='sqrt', random_state=1963466437)
                         0.967741935483871
DecisionTreeClassifier(max_features='sqrt', random_state=1194674174)
```

0.9032258064516129
DecisionTreeClassifier(max_features='sqrt', random_state=602801999)
0.7419354838709677
DecisionTreeClassifier(max_features='sqrt', random_state=1589190063)
0.7096774193548387
DecisionTreeClassifier(max_features='sqrt', random_state=1589512640)
0.7419354838709677
DecisionTreeClassifier(max_features='sqrt', random_state=2055650130)
0.7741935483870968
DecisionTreeClassifier(max_features='sqrt', random_state=2034131043)
0.7741935483870968
DecisionTreeClassifier(max_features='sqrt', random_state=1284876248)
0.8387096774193549
DecisionTreeClassifier(max_features='sqrt', random_state=1292401841)
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DecisionTreeClassifier(max_features='sqrt', random_state=1982038771)
0.7096774193548387
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DecisionTreeClassifier(max_features='sqrt', random_state=768281747)
0.8064516129032258
DecisionTreeClassifier(max_features='sqrt', random_state=507984782)
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DecisionTreeClassifier(max_features='sqrt', random_state=947610023)
0.8709677419354839
DecisionTreeClassifier(max_features='sqrt', random_state=600956192)
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DecisionTreeClassifier(max_features='sqrt', random_state=352272321)
0.8387096774193549
DecisionTreeClassifier(max_features='sqrt', random_state=615697673)
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DecisionTreeClassifier(max_features='sqrt', random_state=160516793)
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DecisionTreeClassifier(max_features='sqrt', random_state=1909838463)
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DecisionTreeClassifier(max_features='sqrt', random_state=1110745632)
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DecisionTreeClassifier(max_features='sqrt', random_state=93837855)
0.7741935483870968
DecisionTreeClassifier(max_features='sqrt', random_state=454869706)
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DecisionTreeClassifier(max_features='sqrt', random_state=1780959476)
0.7096774193548387
DecisionTreeClassifier(max_features='sqrt', random_state=2034098327)
0.8387096774193549
DecisionTreeClassifier(max_features='sqrt', random_state=1136257699)
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DecisionTreeClassifier(max_features='sqrt', random_state=800291326)
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DecisionTreeClassifier(max_features='sqrt', random_state=1177824715)
0.8387096774193549
DecisionTreeClassifier(max_features='sqrt', random_state=1017555826)
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DecisionTreeClassifier(max_features='sqrt', random_state=1959150775)
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DecisionTreeClassifier(max_features='sqrt', random_state=930076700)
0.8709677419354839
DecisionTreeClassifier(max_features='sqrt', random_state=293921570)
0.8709677419354839
DecisionTreeClassifier(max_features='sqrt', random_state=580757632)
0.8387096774193549
DecisionTreeClassifier(max_features='sqrt', random_state=80701568)
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DecisionTreeClassifier(max_features='sqrt', random_state=1392175012)
0.5161290322580645
DecisionTreeClassifier(max_features='sqrt', random_state=505240629)
0.7096774193548387
DecisionTreeClassifier(max_features='sqrt', random_state=642848645)
0.7741935483870968
DecisionTreeClassifier(max_features='sqrt', random_state=481447462)
0.8387096774193549
DecisionTreeClassifier(max_features='sqrt', random_state=954863080)
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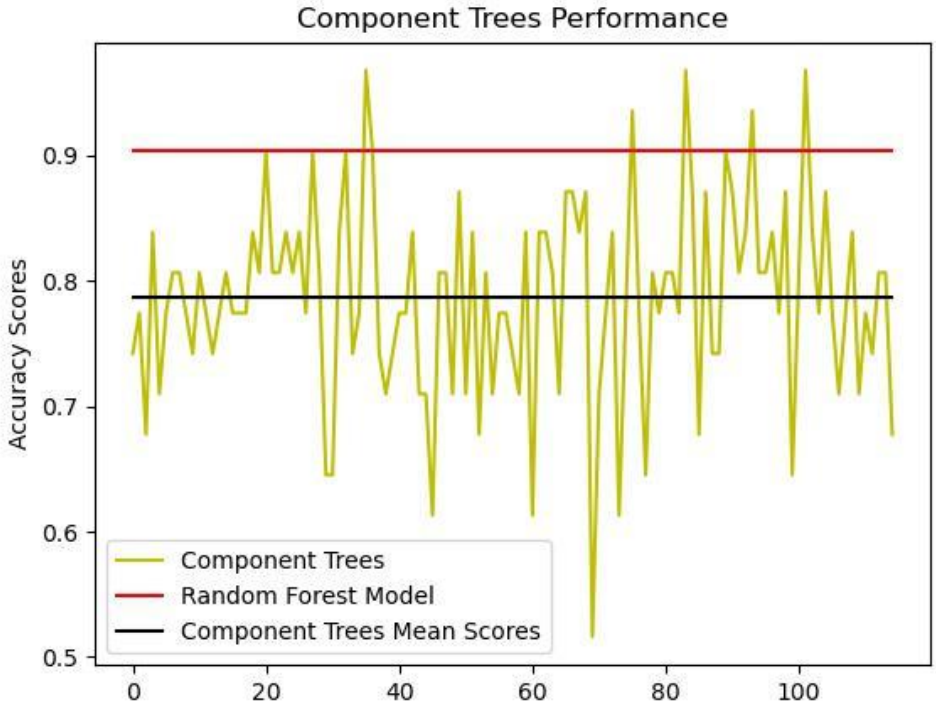
DecisionTreeClassifier(max_features='sqrt', random_state=502227700)
0.7741935483870968
DecisionTreeClassifier(max_features='sqrt', random_state=1659957521)
0.9354838709677419
DecisionTreeClassifier(max_features='sqrt', random_state=1905883471)
0.7741935483870968
DecisionTreeClassifier(max_features='sqrt', random_state=1729147268)
0.6451612903225806
DecisionTreeClassifier(max_features='sqrt', random_state=780912233)
0.8064516129032258
DecisionTreeClassifier(max_features='sqrt', random_state=1932520490)
0.7741935483870968
DecisionTreeClassifier(max_features='sqrt', random_state=1544074682)
0.8064516129032258
DecisionTreeClassifier(max_features='sqrt', random_state=485603871)
0.8064516129032258
DecisionTreeClassifier(max_features='sqrt', random_state=1877037944)
0.7741935483870968
DecisionTreeClassifier(max_features='sqrt', random_state=1728073985)
0.967741935483871
DecisionTreeClassifier(max_features='sqrt', random_state=848819521)
0.8709677419354839
DecisionTreeClassifier(max_features='sqrt', random_state=426405863)
0.6774193548387096
DecisionTreeClassifier(max_features='sqrt', random_state=258666409)
0.8709677419354839
DecisionTreeClassifier(max_features='sqrt', random_state=2017814585)
0.7419354838709677
DecisionTreeClassifier(max_features='sqrt', random_state=716257571)
0.7419354838709677
DecisionTreeClassifier(max_features='sqrt', random_state=657731430)
0.9032258064516129
DecisionTreeClassifier(max_features='sqrt', random_state=732884087)
0.8709677419354839
DecisionTreeClassifier(max_features='sqrt', random_state=734051083)
0.8064516129032258
DecisionTreeClassifier(max_features='sqrt', random_state=903586222)

```
                          0.8387096774193549
DecisionTreeClassifier(max_features='sqrt', random_state=1538251858)
                          0.9354838709677419
 DecisionTreeClassifier(max_features='sqrt', random_state=553734235)
                          0.8064516129032258
DecisionTreeClassifier(max_features='sqrt', random_state=1076688768)
                          0.8064516129032258
DecisionTreeClassifier(max_features='sqrt', random_state=1354754446)
                          0.8387096774193549
 DecisionTreeClassifier(max_features='sqrt', random_state=463129187)
                          0.7741935483870968
DecisionTreeClassifier(max_features='sqrt', random_state=1562125877)
                          0.8709677419354839
DecisionTreeClassifier(max_features='sqrt', random_state=1396067212)
                          0.6451612903225806
 DecisionTreeClassifier(max_features='sqrt', random_state=301492857)
                          0.8064516129032258
 DecisionTreeClassifier(max_features='sqrt', random_state=165035946)
                           0.967741935483871
DecisionTreeClassifier(max_features='sqrt', random_state=1883779156)
                          0.8387096774193549
 DecisionTreeClassifier(max_features='sqrt', random_state=576702667)
                          0.7741935483870968
DecisionTreeClassifier(max_features='sqrt', random_state=2097549636)
                          0.8709677419354839
DecisionTreeClassifier(max_features='sqrt', random_state=1971172102)
                          0.7741935483870968
 DecisionTreeClassifier(max_features='sqrt', random_state=438279108)
                          0.7096774193548387
 DecisionTreeClassifier(max_features='sqrt', random_state=656229423)
                          0.7741935483870968
 DecisionTreeClassifier(max_features='sqrt', random_state=897118847)
                          0.8387096774193549
 DecisionTreeClassifier(max_features='sqrt', random_state=580073460)
                          0.7096774193548387
 DecisionTreeClassifier(max_features='sqrt', random_state=692819075)
                          0.7741935483870968
DecisionTreeClassifier(max_features='sqrt', random_state=2127295436)
                          0.7419354838709677
 DecisionTreeClassifier(max_features='sqrt', random_state=657595236)
                          0.8064516129032258
 DecisionTreeClassifier(max_features='sqrt', random_state=351544500)
                          0.8064516129032258
DecisionTreeClassifier(max_features='sqrt', random_state=1087879144)
                          0.6774193548387096
```

Question B Component Trees Accuracy Scores Analysis

Annotation of the Figures As the below figures show, the red one represents the accuracy scores of the random forest model, and the yellow one represents the accuracy scores of the component trees.



Observations

- The accuracy scores of the individual component trees varies a lot between each other. And th e individual scores ranges from 0.5+ to 0.9+, and the mean score calculated by averaging all the scores of each individuals is `0.7865357643758767`.
- Compared to the mean scores, the actual model score is much higher, and is `0.9032258064516129`.

Findings

- Concluded from the above observations, the random forest model scores are much higher than the mean of the component trees and the majority of the individual component trees. Combined with my understanding of the random forest classifier model, it makes final predictions by aggregating the predictions of multiple trees and taking a majority vote, which helps to reduce the impact of any individual tree's errors and improve the overall accuracy of the model.
- Concern: if the trees in the random forest are quite similar, then even though it would choose the majority choice, but under this situation, the random forest classifier may lead to a bad performance. Hence, we should make the trees in the random forest differs to achieve a higher performance.

Question C

Question C Feature Importance For six Features for each tree

Using the selected component trees in Question B, I generated their associated lists of relative attribute importance values as below.

```
DecisionTreeClassifier(max_features='sqrt', random_state=209652396)
[0.34743972 0.06688596 0.09613247 0.11083523 0.14073868 0.23796794]
DecisionTreeClassifier(max_features='sqrt', random_state=398764591)
[0.0704545  0.12277568 0.11591574 0.34788493 0.08497838 0.25799077]
DecisionTreeClassifier(max_features='sqrt', random_state=924231285)
[0.07819602 0.07496975 0.07340742 0.36696011 0.16622329 0.24024341]
DecisionTreeClassifier(max_features='sqrt', random_state=1478610112)
[0.10069467 0.098169   0.03968471 0.36453001 0.07268564 0.32423597]
DecisionTreeClassifier(max_features='sqrt', random_state=441365315)
[0.36794413 0.10335586 0.07686015 0.09926287 0.05461244 0.29796456]
DecisionTreeClassifier(max_features='sqrt', random_state=1537364731)
[0.22079137 0.07188466 0.05164534 0.07793813 0.17189905 0.40584146]
DecisionTreeClassifier(max_features='sqrt', random_state=192771779)
[0.0549225  0.11671801 0.03003166 0.05624246 0.13228544 0.60979992]
DecisionTreeClassifier(max_features='sqrt', random_state=1491434855)
[0.04202879 0.13918054 0.10559717 0.31951049 0.12454384 0.26913917]
DecisionTreeClassifier(max_features='sqrt', random_state=1819583497)
[0.14524999 0.11394059 0.31645584 0.03366849 0.11418708 0.27649801]
DecisionTreeClassifier(max_features='sqrt', random_state=530702035)
[0.02510466 0.06998405 0.0432837  0.12051246 0.14227029 0.59884482]
DecisionTreeClassifier(max_features='sqrt', random_state=626610453)
[0.06570792 0.19321436 0.11215693 0.08513924 0.10106282 0.44271873]
DecisionTreeClassifier(max_features='sqrt', random_state=1650906866)
[0.32145655 0.13794529 0.04047477 0.05339755 0.12036099 0.32636485]
DecisionTreeClassifier(max_features='sqrt', random_state=1879422756)
[0.0632979  0.06045249 0.0508958  0.07462037 0.05938524 0.6913482 ]
DecisionTreeClassifier(max_features='sqrt', random_state=1277901399)
[0.05267909 0.08956992 0.19038568 0.03426295 0.05718535 0.57591701]
DecisionTreeClassifier(max_features='sqrt', random_state=1682652230)
[0.41919304 0.14903491 0.         0.11603395 0.06621477 0.24952334]
DecisionTreeClassifier(max_features='sqrt', random_state=243580376)
[0.05765295 0.0322834  0.05611742 0.15057501 0.11509883 0.5882724 ]
DecisionTreeClassifier(max_features='sqrt', random_state=1991416408)
[0.05704782 0.11788846 0.29789974 0.08013284 0.14927086 0.29776027]
DecisionTreeClassifier(max_features='sqrt', random_state=1171049868)
[0.05834843 0.08615375 0.07441213 0.3310427  0.16314021 0.28690279]
DecisionTreeClassifier(max_features='sqrt', random_state=1646868794)
[0.02729737 0.09027287 0.13939624 0.06807388 0.05738474 0.6175749 ]
```

DecisionTreeClassifier(max_features='sqrt', random_state=2051556033)
[0.05778124 0.05567375 0.06761095 0.07610747 0.07638609 0.6664405]
DecisionTreeClassifier(max_features='sqrt', random_state=1252949478)
[0.11131064 0.06321312 0.07040658 0.30010276 0.05978129 0.39518562]
DecisionTreeClassifier(max_features='sqrt', random_state=1340754471)
[0.38016551 0.08868927 0.   0.08639426 0.14093518 0.30381578]
DecisionTreeClassifier(max_features='sqrt', random_state=124102743)
[0.31983352 0.16391856 0.06020317 0.14154513 0.10926201 0.20523761]
DecisionTreeClassifier(max_features='sqrt', random_state=2061486254)
[0.36005177 0.08621668 0.0701134 0.05126966 0.09935207 0.33299642]
DecisionTreeClassifier(max_features='sqrt', random_state=292249176)
[0.01068674 0.07563093 0.35135043 0.14908363 0.0959677 0.31728057]
DecisionTreeClassifier(max_features='sqrt', random_state=1686997841)
[0.01980846 0.06818435 0.03972797 0.14065926 0.09618113 0.63543882]
DecisionTreeClassifier(max_features='sqrt', random_state=1827923621)
[0.12746359 0.03479536 0.0034941 0.284094   0.09373704 0.45641591]
DecisionTreeClassifier(max_features='sqrt', random_state=1443447321)
[0.0263564 0.05321395 0.07230605 0.05800153 0.10634329 0.68377877]
DecisionTreeClassifier(max_features='sqrt', random_state=305097549)
[0.08074532 0.14812023 0.0488653 0.05712348 0.10170317 0.56344249]
DecisionTreeClassifier(max_features='sqrt', random_state=1449105480)
[0.286469   0.13844493 0.12545862 0.10501089 0.18304802 0.16156854]
DecisionTreeClassifier(max_features='sqrt', random_state=374217481)
[0.05511151 0.26149464 0.12011367 0.21592076 0.04978345 0.29757598]
DecisionTreeClassifier(max_features='sqrt', random_state=636393364)
[0.0533855 0.11336019 0.30462837 0.09351601 0.12623913 0.30887081]
DecisionTreeClassifier(max_features='sqrt', random_state=86837363)
[0.07865872 0.08573112 0.11232419 0.13983481 0.16212177 0.42132939]
DecisionTreeClassifier(max_features='sqrt', random_state=1581585360)
[0.05920415 0.08787007 0.41387913 0.13019566 0.08740737 0.22144362]
DecisionTreeClassifier(max_features='sqrt', random_state=1428591347)
[0.10658044 0.24124526 0.12467387 0.13263493 0.16887361 0.22599189]
DecisionTreeClassifier(max_features='sqrt', random_state=1963466437)
[0.04085715 0.06479862 0.36548217 0.08185986 0.175853   0.2711492]
DecisionTreeClassifier(max_features='sqrt', random_state=1194674174)
[0.36976261 0.10800231 0.05704066 0.15412902 0.192055   0.11901041]
DecisionTreeClassifier(max_features='sqrt', random_state=602801999)
[0.0484159 0.0487353 0.10991839 0.46939448 0.12409158 0.19944434]
DecisionTreeClassifier(max_features='sqrt', random_state=1589190063)
[0.0179187 0.06573194 0.07225228 0.12618913 0.05863493 0.65927302]
DecisionTreeClassifier(max_features='sqrt', random_state=1589512640)
[0.125002   0.0465147 0.06522041 0.26043697 0.19923626 0.30358965]
DecisionTreeClassifier(max_features='sqrt', random_state=2055650130)
[0.03465266 0.08834858 0.06736404 0.06986443 0.08967668 0.65009362]
DecisionTreeClassifier(max_features='sqrt', random_state=2034131043)
[0.0452859 0.04120036 0.0679091 0.10695237 0.12131399 0.61733829]
DecisionTreeClassifier(max_features='sqrt', random_state=1284876248)
[0.10108784 0.08004884 0.29631522 0.08167436 0.16283487 0.27803886]
DecisionTreeClassifier(max_features='sqrt', random_state=1292401841)
[0.17026779 0.07282673 0.04343398 0.3088798 0.08531244 0.31927926]
DecisionTreeClassifier(max_features='sqrt', random_state=1982038771)
[0.12068012 0.04879925 0.42469528 0.06722838 0.07227117 0.2663258]
DecisionTreeClassifier(max_features='sqrt', random_state=87950109)
[0.13362681 0.11715664 0.34591486 0.12893029 0.05559194 0.21877945]
DecisionTreeClassifier(max_features='sqrt', random_state=1204863635)
[0.04753238 0.09140618 0.03929189 0.12603119 0.07366376 0.6220746]
DecisionTreeClassifier(max_features='sqrt', random_state=768281747)
[0.15550292 0.03828647 0.10568638 0.38101589 0.04769744 0.27181089]
DecisionTreeClassifier(max_features='sqrt', random_state=507984782)
[0.03930105 0.12590563 0.28008018 0.20503982 0.1398194 0.20985391]
DecisionTreeClassifier(max_features='sqrt', random_state=947610023)
[0.01665355 0.02193916 0.0331283 0.16554322 0.18662717 0.57610859]
DecisionTreeClassifier(max_features='sqrt', random_state=600956192)
[0.04003656 0.08779017 0.06334442 0.11139794 0.07487894 0.62255196]
DecisionTreeClassifier(max_features='sqrt', random_state=352272321)
[0.10669355 0.11942664 0.03081629 0.28553516 0.13628694 0.32124142]
DecisionTreeClassifier(max_features='sqrt', random_state=615697673)
[0.3386003 0.08711497 0.13081975 0.15886308 0.06668229 0.21791961]
DecisionTreeClassifier(max_features='sqrt', random_state=160516793)
[0.12629416 0.04419408 0.02822362 0.33818226 0.21520308 0.2479028]
DecisionTreeClassifier(max_features='sqrt', random_state=1909838463)
[0.13783948 0.05936108 0.19789719 0.18580645 0.09283705 0.32625874]
DecisionTreeClassifier(max_features='sqrt', random_state=1110745632)
[0.11675543 0.08953569 0.10927283 0.26145753 0.10008016 0.32289837]
DecisionTreeClassifier(max_features='sqrt', random_state=93837855)
[0.14294937 0.07843927 0.08695443 0.31343329 0.1332696 0.24495405]
DecisionTreeClassifier(max_features='sqrt', random_state=454869706)
[0.08159374 0.03382821 0.35622231 0.08878521 0.17675858 0.26281194]
DecisionTreeClassifier(max_features='sqrt', random_state=1780959476)
[0.07885916 0.10443928 0.11089514 0.05015521 0.05453662 0.60111459]
DecisionTreeClassifier(max_features='sqrt', random_state=2034098327)
[0.04393128 0.10780342 0.09557158 0.03702596 0.11812886 0.5975389]
DecisionTreeClassifier(max_features='sqrt', random_state=1136257699)
[0.21559404 0.02093023 0.05852361 0.29777726 0.21294479 0.19423007]
DecisionTreeClassifier(max_features='sqrt', random_state=800291326)
[0.27573203 0.15269326 0.02272751 0.10843996 0.11826573 0.32214152]
DecisionTreeClassifier(max_features='sqrt', random_state=1177824715)
[0.41057976 0.11311207 0.04149588 0.0433736 0.09971018 0.29172851]
DecisionTreeClassifier(max_features='sqrt', random_state=1017555826)
[0.0509112 0.06489457 0.06563315 0.03745332 0.17069819 0.61040958]
DecisionTreeClassifier(max_features='sqrt', random_state=1959150775)
[0.34404316 0.06772821 0.10321543 0.16716273 0.08667082 0.23117965]
DecisionTreeClassifier(max_features='sqrt', random_state=930076700)
[0.05276   0.06897285 0.07584642 0.12826921 0.11462991 0.5595216]
DecisionTreeClassifier(max_features='sqrt', random_state=293921570)
[0.03796185 0.13105751 0.06597808 0.0778511 0.05790695 0.62924451]
DecisionTreeClassifier(max_features='sqrt', random_state=580757632)
[0.0775731 0.08978542 0.03256879 0.16963629 0.07126006 0.55917635]
DecisionTreeClassifier(max_features='sqrt', random_state=80701568)
[0.07526654 0.11555722 0.36041927 0.04917359 0.08858618 0.31099721]
DecisionTreeClassifier(max_features='sqrt', random_state=1392175012)
[0.14733084 0.08341027 0.20156191 0.36051311 0.11492905 0.09225482]
DecisionTreeClassifier(max_features='sqrt', random_state=505240629)
[0.27279999 0.03761398 0.07020699 0.11980252 0.1698699 0.32970662]
DecisionTreeClassifier(max_features='sqrt', random_state=642848645)
[0.31058243 0.09132156 0.03934485 0.11477177 0.10699218 0.3369872]
DecisionTreeClassifier(max_features='sqrt', random_state=481447462)
[0.0206101 0.12690045 0.08954202 0.08828914 0.0248403 0.64981799]
DecisionTreeClassifier(max_features='sqrt', random_state=954863080)
[0.0765737 0.06444468 0.21498127 0.28725213 0.   0.35674822]
DecisionTreeClassifier(max_features='sqrt', random_state=502227700)
[0.13176494 0.06042738 0.19425201 0.08805615 0.16429983 0.36119969]

```
DecisionTreeClassifier(max_features='sqrt', random_state=1659957521)
 [0.03734525 0.02747262 0.05508266 0.11905828 0.13071207 0.63032912]
DecisionTreeClassifier(max_features='sqrt', random_state=1905883471)
 [0.08221859 0.11144661 0.17030589 0.26937061 0.11611361 0.2505447 ]
DecisionTreeClassifier(max_features='sqrt', random_state=1729147268)
 [0.06069946 0.16187134 0.04092704 0.09347168 0.15980699 0.48322349]
 DecisionTreeClassifier(max_features='sqrt', random_state=780912233)
 [0.06402494 0.04436765 0.06252052 0.0554821  0.1295037  0.64410109]
DecisionTreeClassifier(max_features='sqrt', random_state=1932520490)
 [0.02909393 0.15310076 0.20874867 0.10527422 0.09217223 0.41161018]
DecisionTreeClassifier(max_features='sqrt', random_state=1544074682)
 [0.36051173 0.09992588 0.07360433 0.07993071 0.13840348 0.24762387]
 DecisionTreeClassifier(max_features='sqrt', random_state=485603871)
 [0.0893434  0.06761247 0.01639248 0.12384878 0.10996592 0.59283694]
DecisionTreeClassifier(max_features='sqrt', random_state=1877037944)
 [0.24701794 0.04702269 0.03416974 0.12037961 0.18573915 0.36567088]
DecisionTreeClassifier(max_features='sqrt', random_state=1728073985)
 [0.088103   0.09655952 0.04377152 0.07498743 0.11610588 0.58047265]
 DecisionTreeClassifier(max_features='sqrt', random_state=848819521)
 [0.11836996 0.04856513 0.07374171 0.11085206 0.04823387 0.60023727]
 DecisionTreeClassifier(max_features='sqrt', random_state=426405863)
 [0.28897332 0.13447774 0.11486443 0.08353963 0.1558868  0.22225808]
 DecisionTreeClassifier(max_features='sqrt', random_state=258666409)
 [0.08124079 0.03121456 0.09543327 0.06787232 0.08048223 0.64375683]
DecisionTreeClassifier(max_features='sqrt', random_state=2017814585)
 [0.28833579 0.0293282  0.07492698 0.13570605 0.1857579  0.28594507]
 DecisionTreeClassifier(max_features='sqrt', random_state=716257571)
 [0.05905285 0.1182783  0.31556553 0.12569725 0.04306812 0.33833794]
 DecisionTreeClassifier(max_features='sqrt', random_state=657731430)
 [0.03943664 0.06606328 0.05536218 0.08410091 0.1170502  0.63798679]
 DecisionTreeClassifier(max_features='sqrt', random_state=732884087)
 [0.27763363 0.02201264 0.05194222 0.15828786 0.11552242 0.37460124]
 DecisionTreeClassifier(max_features='sqrt', random_state=734051083)
 [0.12334795 0.06184697 0.08980592 0.21146821 0.09730292 0.41622805]
 DecisionTreeClassifier(max_features='sqrt', random_state=903586222)
 [0.10130044 0.04095862 0.07296618 0.09924924 0.12221017 0.56331534]
DecisionTreeClassifier(max_features='sqrt', random_state=1538251858)
 [0.06643119 0.02197649 0.02077099 0.10795411 0.13950574 0.64336149]
 DecisionTreeClassifier(max_features='sqrt', random_state=553734235)
 [0.0179042  0.13735373 0.27850272 0.18871573 0.17352385 0.20399978]
DecisionTreeClassifier(max_features='sqrt', random_state=1076688768)
 [0.03904137 0.0377934  0.1282061  0.06237319 0.06945357 0.66313237]
DecisionTreeClassifier(max_features='sqrt', random_state=1354754446)
 [0.25415452 0.06811137 0.13621371 0.09847733 0.13553819 0.30750488]
 DecisionTreeClassifier(max_features='sqrt', random_state=463129187)
 [0.32940772 0.06205173 0.07114865 0.12423858 0.16225292 0.25090039]
DecisionTreeClassifier(max_features='sqrt', random_state=1562125877)
 [0.09162818 0.04730917 0.0090824  0.3349238  0.16398359 0.35307286]
DecisionTreeClassifier(max_features='sqrt', random_state=1396067212)
 [0.09398372 0.09722893 0.32099875 0.13397398 0.15660989 0.19720474]
 DecisionTreeClassifier(max_features='sqrt', random_state=301492857)
 [0.09028728 0.12434295 0.17985959 0.13360432 0.09487305 0.3770328 ]
 DecisionTreeClassifier(max_features='sqrt', random_state=165035946)
 [0.1051823  0.07718866 0.04040011 0.10510364 0.12552292 0.54660237]
DecisionTreeClassifier(max_features='sqrt', random_state=1883779156)
 [0.03972676 0.03590136 0.03613877 0.35190526 0.04272375 0.49360411]
 DecisionTreeClassifier(max_features='sqrt', random_state=576702667)
 [0.07379895 0.10858406 0.30272978 0.03420779 0.10893643 0.37174299]
DecisionTreeClassifier(max_features='sqrt', random_state=2097549636)
 [0.04955924 0.02345712 0.39512797 0.0829612  0.11077074 0.33812373]
DecisionTreeClassifier(max_features='sqrt', random_state=1971172102)
 [0.04778386 0.13399473 0.07455469 0.34455981 0.14238775 0.25671915]
 DecisionTreeClassifier(max_features='sqrt', random_state=438279108)
 [0.11579044 0.06428075 0.3428078  0.15752302 0.1896888  0.1299092 ]
 DecisionTreeClassifier(max_features='sqrt', random_state=656229423)
 [0.06587906 0.05607583 0.28908613 0.16855401 0.08452499 0.33587998]
 DecisionTreeClassifier(max_features='sqrt', random_state=897118847)
 [0.09641396 0.06018287 0.10765326 0.37170217 0.13729444 0.2267533 ]
 DecisionTreeClassifier(max_features='sqrt', random_state=580073460)
 [0.270719   0.05426182 0.17397563 0.0380249  0.23065356 0.2323651 ]
 DecisionTreeClassifier(max_features='sqrt', random_state=692819075)
 [0.06161059 0.09449211 0.05833471 0.08919481 0.00549685 0.69087093]
DecisionTreeClassifier(max_features='sqrt', random_state=2127295436)
 [0.04404368 0.11070336 0.26370302 0.16802957 0.07056821 0.34295216]
 DecisionTreeClassifier(max_features='sqrt', random_state=657595236)
 [0.30141542 0.09267196 0.07190997 0.04065186 0.12240575 0.37094504]
 DecisionTreeClassifier(max_features='sqrt', random_state=351544500)
 [0.05452705 0.04608159 0.0579415  0.2747659  0.12308972 0.44359423]
DecisionTreeClassifier(max_features='sqrt', random_state=1087879144)
 [0.15826342 0.19008542 0.15127259 0.10691329 0.21636501 0.17710026]
 Model Scores:  0.9032258064516129 Mean scores:  0.7865357643758767
```

Question C Analysis

Annotation I generated the feature importance of the 6 features (Figure 1) by taking the feature importance result from the 115 component trees. I also merged the feature importance of the 6 features into one graph (Figure 2). I also calculated the mean feature importance for each features by averaging the feature importance from the 115 component trees.

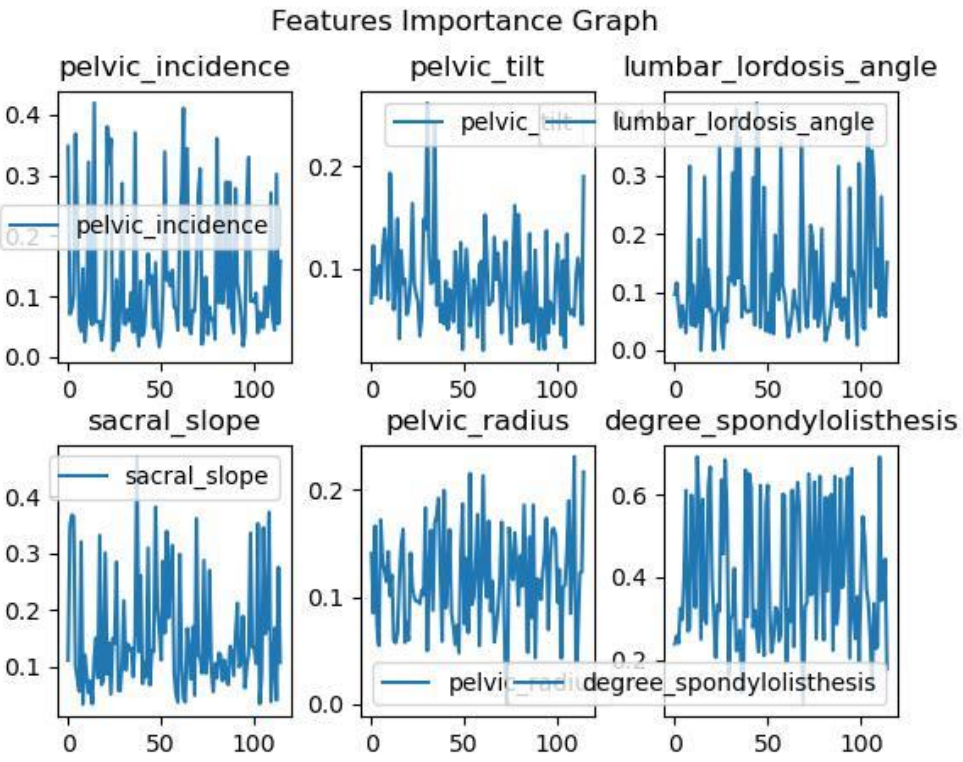


Figure 1 Features Importance for The 6 features

Observation From Figure 1

- The above figure shows the distributions of the feature importance for each feature:
  - Pelvic incidence: 0+ to 0.4+
  - Pelvic tilt: 0+ to 0.2+
  - Lumbar lordosis angle: 0+ to 0.4+
  - Sacral slope: 0+ to 0.4+
  - Pelvic radius: 0+ to 0.2+
  - Degree spondylolisthesis: 0+ to 0.6+

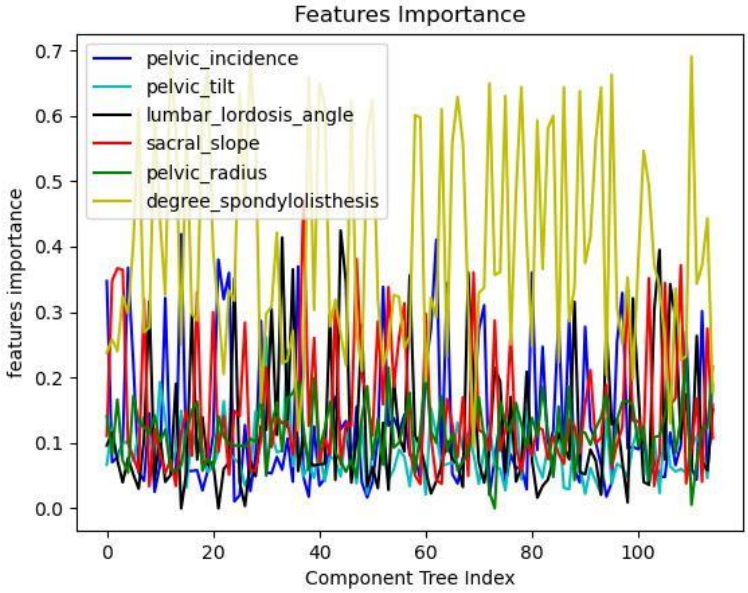


Figure 2:Feature Importance Overview

Observation from Figure 2

- The feature importance of degree spondylolisthesis is appreciably higher than that of the other fie features.

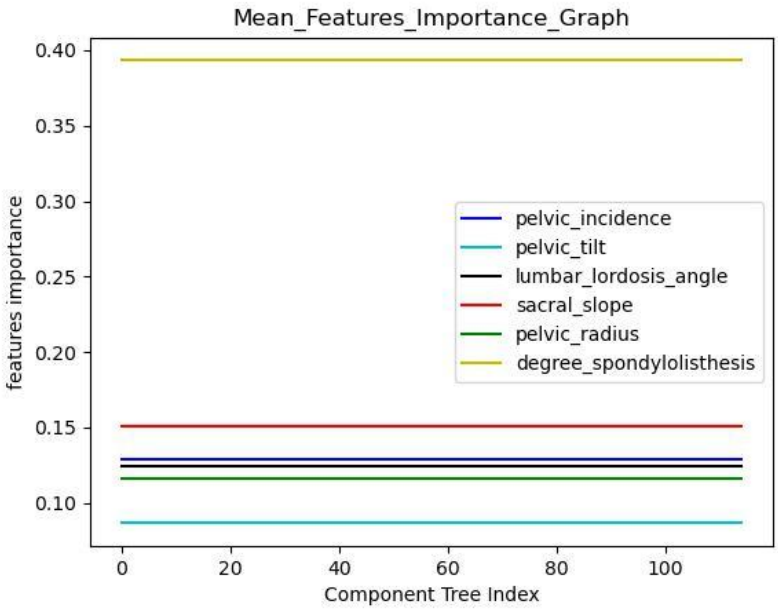


Figure 3: Mean Features Importance for the 6 features

Mean Feature Importance Data

```
Mean Feature Importance of pelvic_incidence:  0.12863396105770825
Mean Feature Importance of pelvic_tilt:  0.08667147442890695
Mean Feature Importance of lumbar_lordosis_angle:  0.12414353670988675
Mean Feature Importance of sacral_slope:  0.15122335909960322
Mean Feature Importance of pelvic_radius:  0.11613742117405064
Mean Feature Importance of degree_spondylolisthesis: 0.3931902475298444
```

Observation from Figure 3 and Mean Feature Importance Data

- Form the above figure, it's obvious that the mean feature importance of degree spondylolisthesis is well above that of the other five features
- The mean feature importance of pelvic tilt is below 0.10, which is quite lower than the others
- Except for the above 2 features, the mean feature importance of the rest 4 features are quite close, and is around 0.10-0.15.

Findings

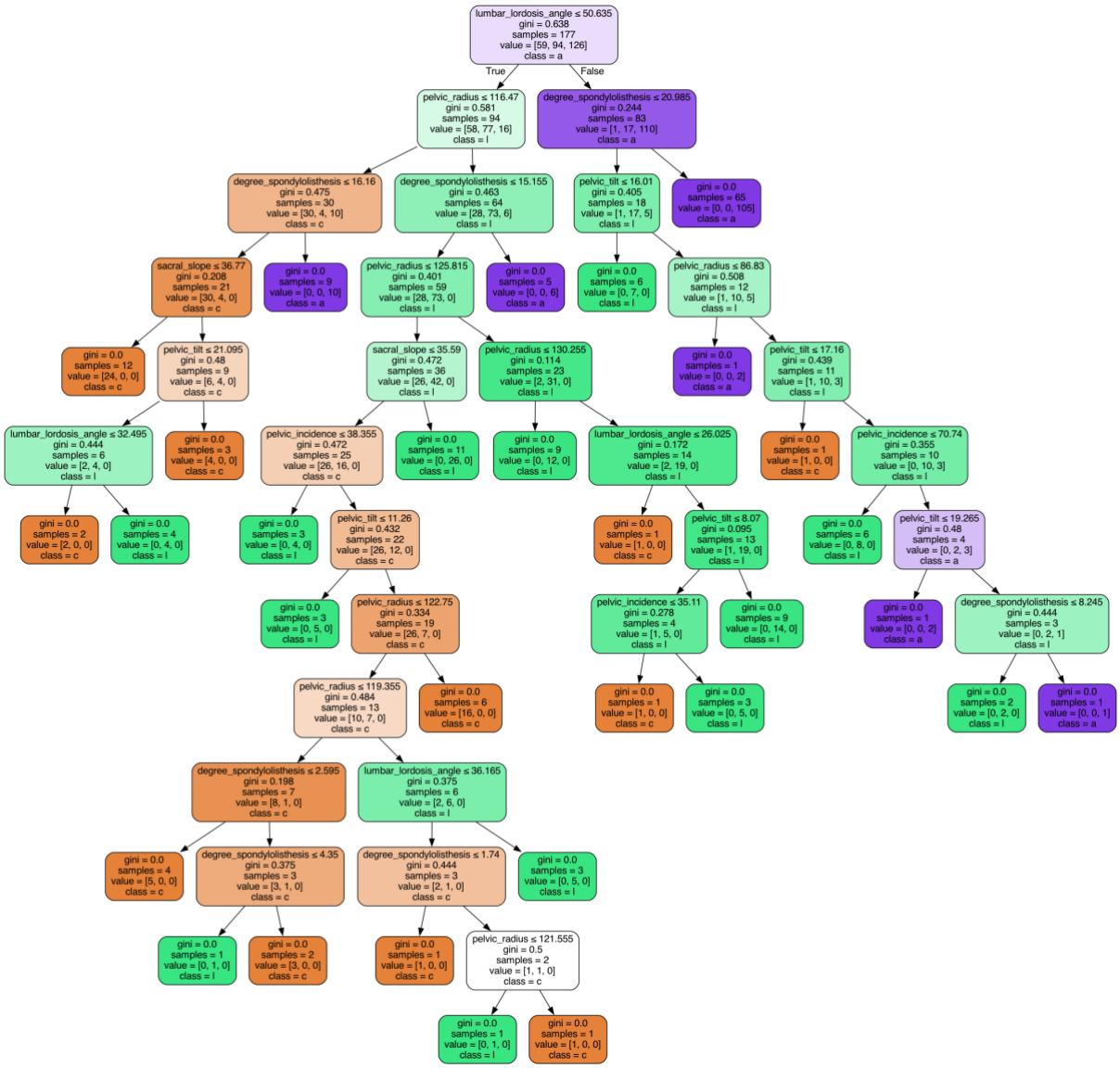
- From the above figures and analysis, it's easy to conclude that the degree spondylolisthesis plays a relatively high importance among all the six features.
- The feature importance in different trees varies a lot.

Question C Analysis with The Decision Tree Graph of The Component Trees

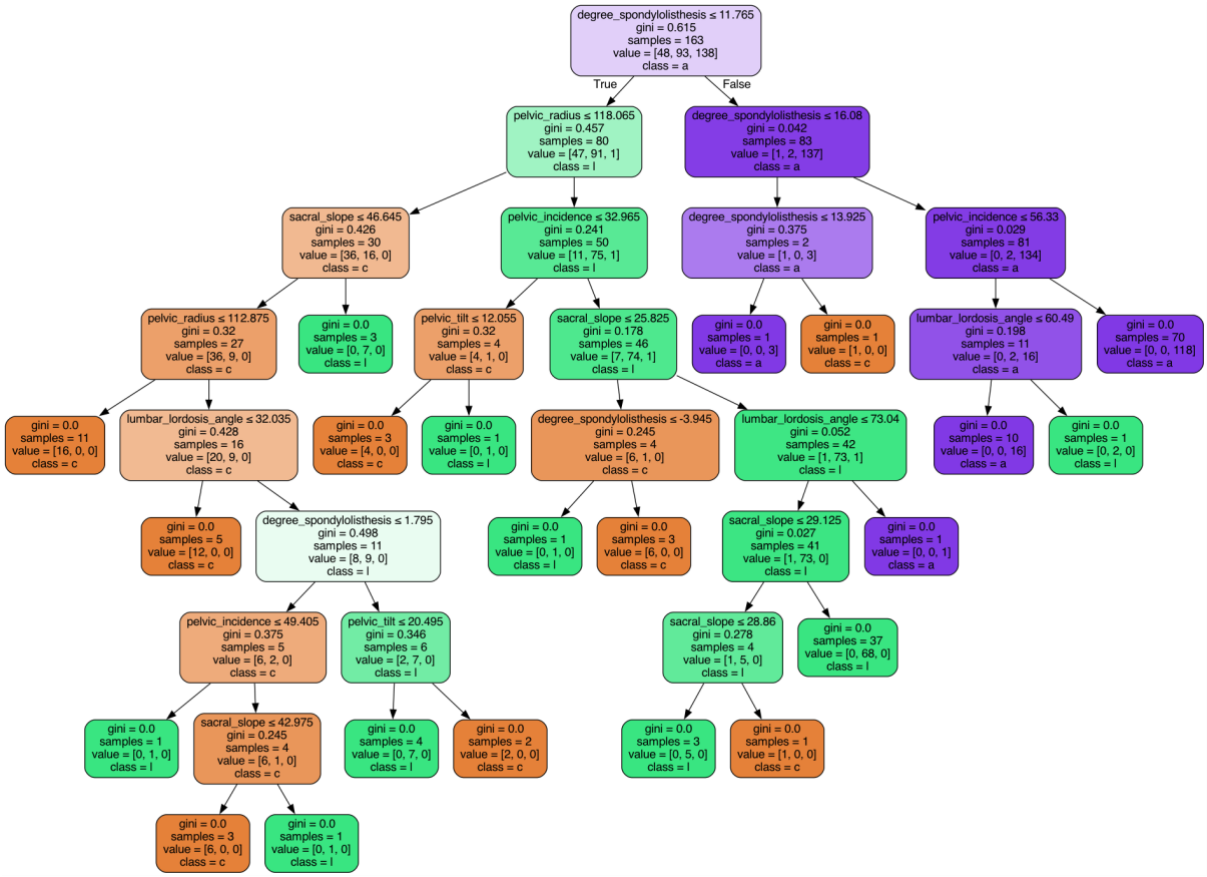
Component Trees

I select several component tree graphs with relatively high performance of the visualized decision trees here. It has a very good performance.

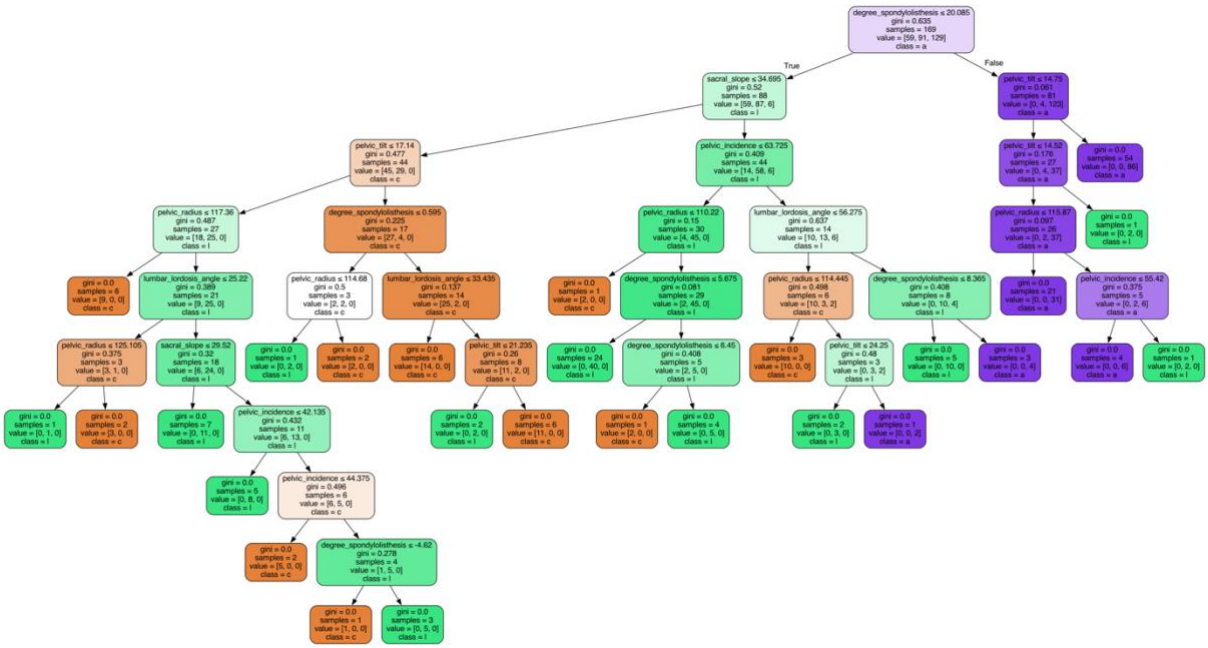
`Component Tree with accuracy score of 0.967741935483871`



Component Tree with accuracy score of 0.9354838709677419



Component Tree with accuracy score of 0.967741935483871



Findings

Actually, I found there are several identical trees in the forest.

Question D

Question D Analysis 1 with The Selected Model in Question B

I generate the results with the following parameters:

- Test Size: 0.1
- Train Split Random State: 27

Observations

- I constructed the Gaussian Naïve Bayes Classifier, and use it to predict the result, and got the accuracy scores of 0.8064516129032258.
- Compared to the random forest classifier model, the Gaussian Naïve Bayes Classifier model has an appreciably lower accuracy scores.
- However, the training and running speed of the Gaussian Naïve Bayes Classifier model is much faster than the random forest model.

Findings

In general, the Naive Bayes model is a simpler and faster model than the random forest model, but it has relatively lower accuracy scores and generalization performance. On the other hand, the random forest model may have higher accuracy and generalization performance, but its computation cost is much higher and harder to interpret.

Potential Reasons (Referred from internet)

In summary, the choice of which classifier to use depends on the specific dataset and problem at hand, as well as the trade-off between performance, complexity, interpretability, and computational resources. While the Gaussian Naive Bayes classifier is a simple and fast algorithm, it may have lower performance than the random forest classifier in some cases, especially if the data has complex relationships or interactions between the features.

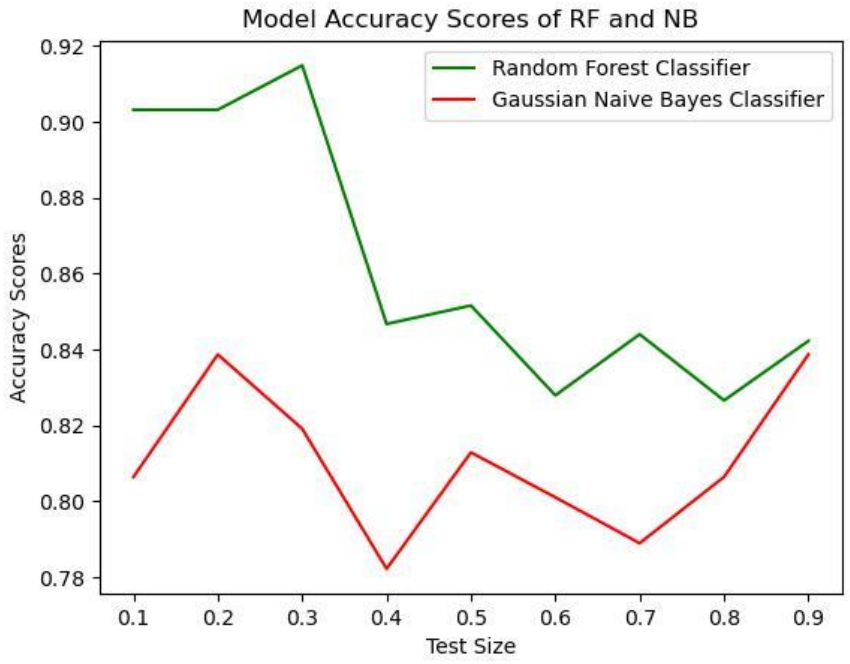
Question D Analysis 2 with Test Size ranging from 0.1 to 0.9

Methodology

I generated the best accuracy scores for the random forest classifier with each test size from 0.1 to 0.9, and also generated the Gaussian Naïve Bayes Classifier result with the test size of 0.1-0.9.

Observation

As the graph shown, it's easy to see that with different test size, the accuracy scores of gaussian naïve bayes classifier is always much poorer than that of random forest classifier.



Potential Reasons (Referred from internet)

- Robustness to outliers: The random forest classifier is less sensitive to outliers and noise in the data than the Gaussian Naive Bayes classifier, which can lead to better performance on noisy or outlier-prone datasets.

- Feature selection and importance estimation: The random forest classifier can perform feature selection and estimate feature importance based on the feature's contribution to the model's performance, which can help to identify the most relevant features for the classification task.

- Ensembling and generalization: The random forest classifier combines the predictions of multiple decision trees and can generalize well to new and unseen data, while the Gaussian Naive Bayes classifier may overfit to the training data if the distributional assumptions are violated.

Appendix

My Source GitHub

My code and related figures for this project is store in the GitHub Repository:
https://github.com/alfreddLUO/Random-Forest-and-Naive-Bayes-Classifier-Assignment