MR Görüntülerinden Alzheimer Tespiti Makine Öğrenmesi

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***Özet*— Bu raporda, MR görüntülerinden Alzheimer hastalığını tespit etmek için kullanılan Dönüştürücü (Transformer) modellerinin uygulanması detaylandırılmaktadır. Bu çalışma, Google Colab üzerinde gerçekleştirilmiş olup, karışık hassasiyetli eğitim kullanılarak verimlilik artırılmış ve 5 katmanlı çapraz doğrulama ile performans değerlendirilmesi yapılmıştır. Performans metrikleri arasında doğruluk, kesinlik, geri çağırma, F1-skora, özgüllük, MCC ve AUC yer almaktadır. Veri artırma teknikleri, modelin genelleme yeteneğini artırmak için kullanılmıştır.**

Anahtar Kelimeler*— *Alzheimer, MR Görüntüleri, Dönüştürücü Modeller, ViT, BeiT, DeiT, Swin, LeViT, Performans Metrikleri

I. GIRIŞ

Alzheimer hastalığının artan yaygınlığı, gelişmiş tanı araçlarını gerektirmektedir. Bu çalışmada, çeşitli görüntü sınıflandırma görevlerinde üstün performans göstermiş olan Dönüştürücü (Transformer) modelleri kullanılmıştır. Amacımız, MR görüntülerini dört kategoriye ayırmaktır: Hafif Bozukluk, Orta Bozukluk, Bozukluk Yok ve Çok Hafif Bozukluk.

II. YÖNTEM

A. *Veri Hazırlığı*

Veri seti, dört sınıfa ayrılmış MR görüntülerinden oluşmaktadır. Veri artırma işlemleri, modelin dayanıklılığını artırmak için "ImageDataGenerator" sınıfı kullanılarak gerçekleştirilmiştir. Veri, model performansını doğrulamak için 5 katmanlı çapraz doğrulama kullanılarak bölünmüştür.

B. *Model Mimarisi*

Bu çalışmada kullanılan modeller:

- Google ViT-B16
- Microsoft BeiT
- LeViT
- DEViT
- Swin

Her model, önceden eğitilmiş ağırlıklarla kullanılmıştır. Modeller, dört sınıfı içerecek şekilde son katmanı değiştirilerek veri setimiz üzerinde ince ayar yapılmıştır. Karışık hassasiyetli eğitim, eğitim sürecini hızlandırmak için etkinleştirilmiştir.

III. MODEL EĞITIM PARAMETRELERI

1. Google ViT-B16
   - Epoch: 15
   - Batch Size: 32
   - Öğrenme Oranı: 0.0001

2. Microsoft BeiT
   - Epoch: 10
   - Batch Size: 32
   - Öğrenme Oranı: 0.0001

3. LeViT 384
   - Epoch: 20
   - Batch Size: 32
   - Öğrenme Oranı: 0.0001

4. DEViT base_patch_16_224
   - Epoch: 10
   - Batch Size: 32
   - Öğrenme Oranı: 0.0001

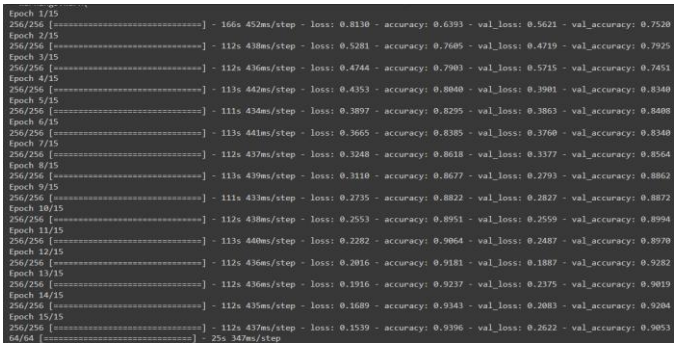
5. Swin base_patch4_window7_224
   - Epoch: 15
   - Batch Size: 32
   - Öğrenme Oranı: 0.0001

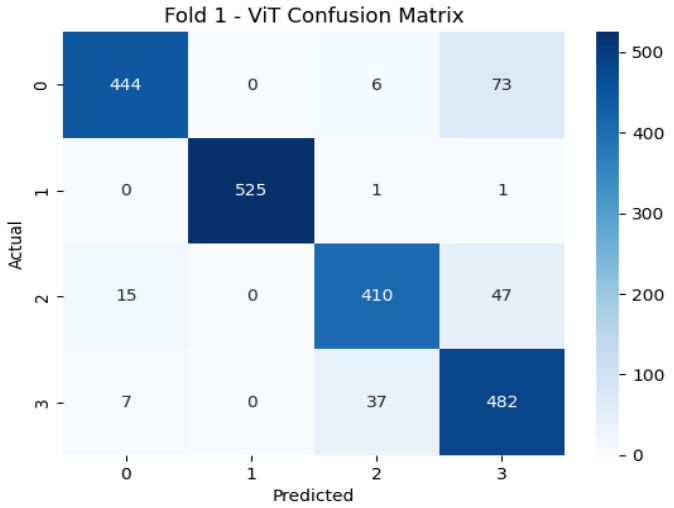
IV. SONUÇLAR

Her modelin 5 katmanlı çapraz doğrulama sonuçları aşağıda detaylandırılmıştır:

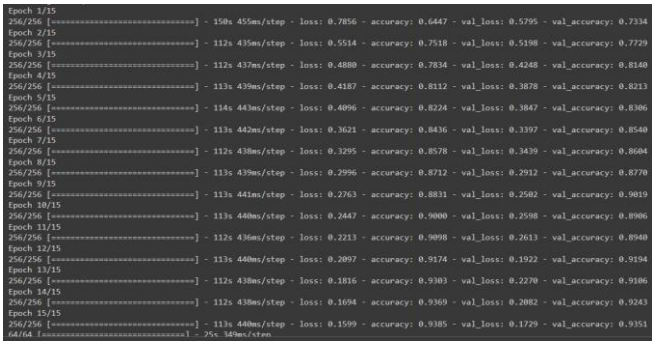
Google ViT-B16

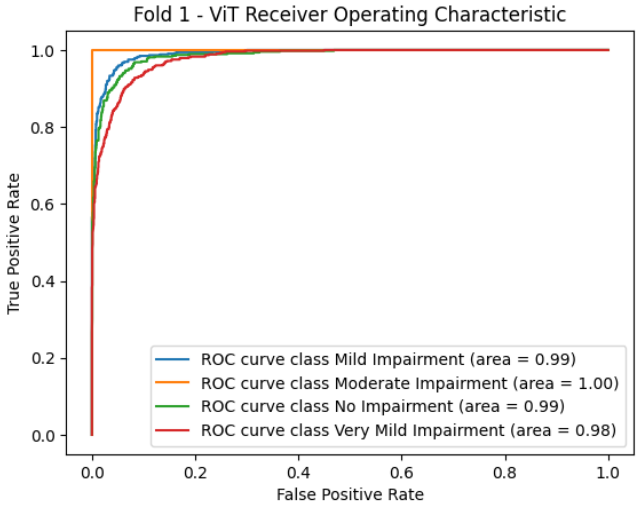
ViT Fold 1

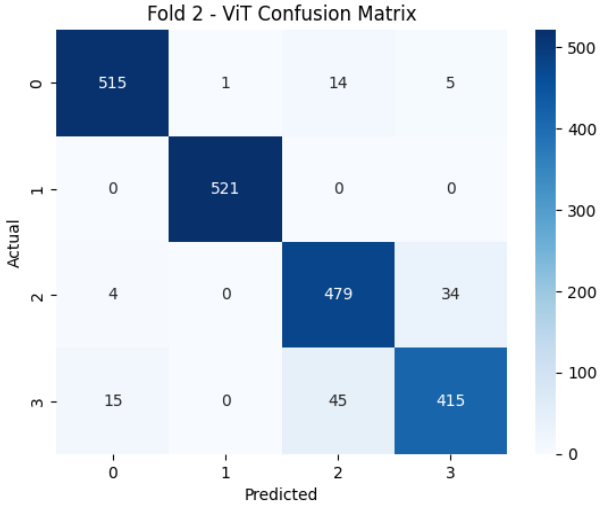


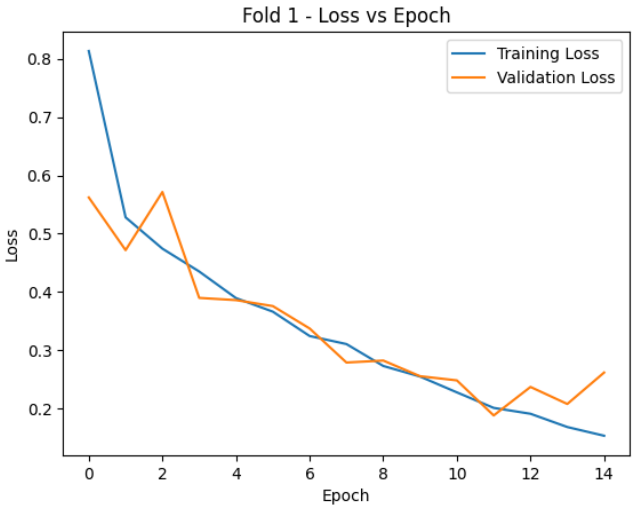

Fold 1 - ViT Confusion Matrix
Actual
Predicted
444
0
6
73
0
525
1
1
15
0
410
47
7
0
37
482

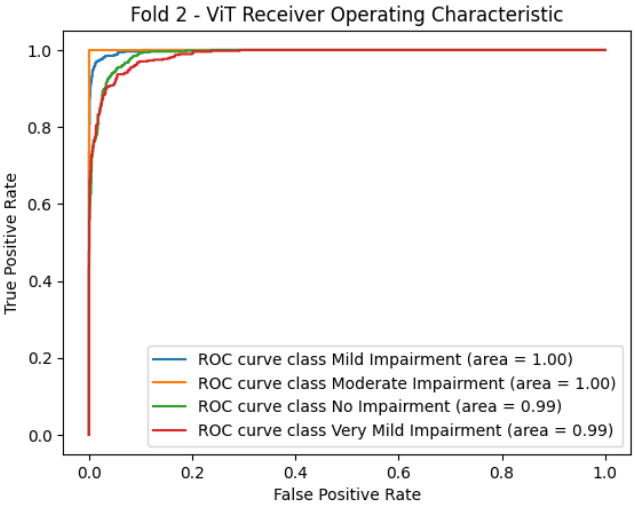
ViT Fold 2

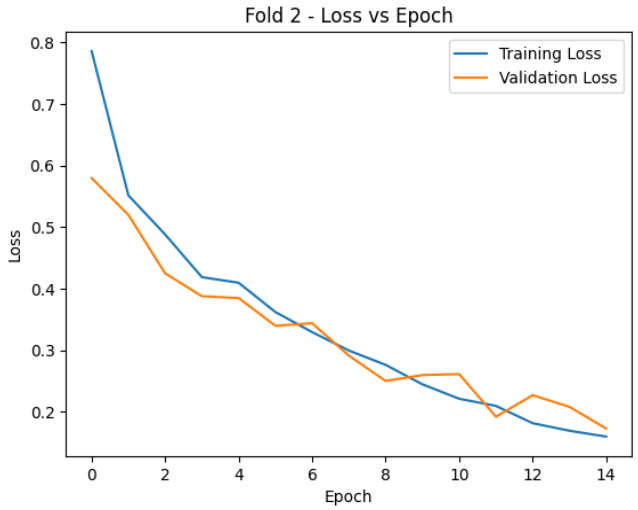

Epoch 1/15
Epoch 2/15
Epoch 3/15
Epoch 4/15
Epoch 5/15
Epoch 6/15
Epoch 7/15
Epoch 8/15
Epoch 9/15
Epoch 10/15
Epoch 11/15
Epoch 12/15
Epoch 13/15
Epoch 14/15
Epoch 15/15

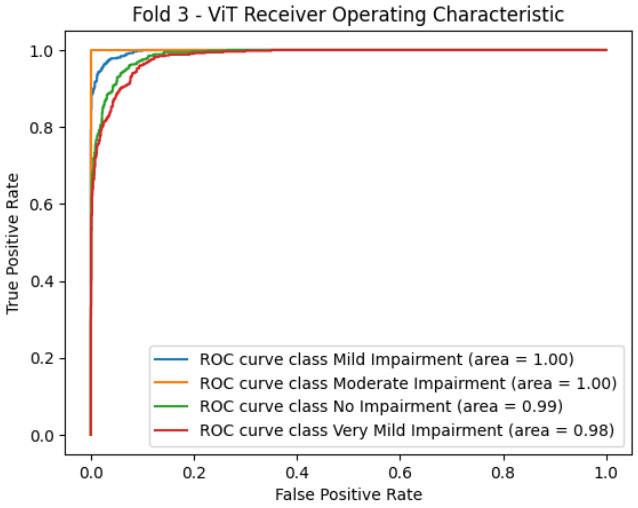

Fold 1 - ViT Receiver Operating Characteristic
True Positive Rate
False Positive Rate
ROC curve class Mild Impairment (area = 0.99)
ROC curve class Moderate Impairment (area = 1.00)
ROC curve class No Impairment (area = 0.99)
ROC curve class Very Mild Impairment (area = 0.98)


Fold 2 - ViT Confusion Matrix
Actual
Predicted
515
1
14
5
0
521
0
0
4
0
479
34
15
0
45
415

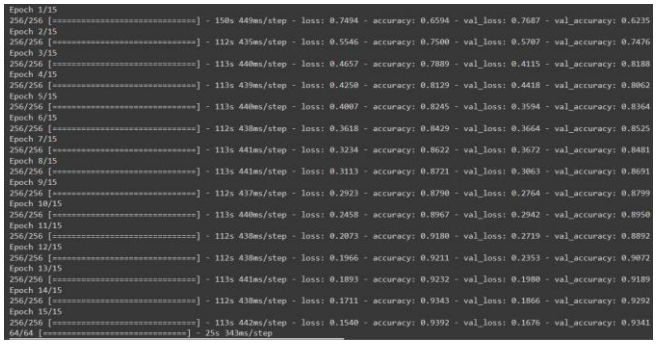

Fold 1 - Loss vs Epoch
Loss
Epoch
Training Loss
Validation Loss

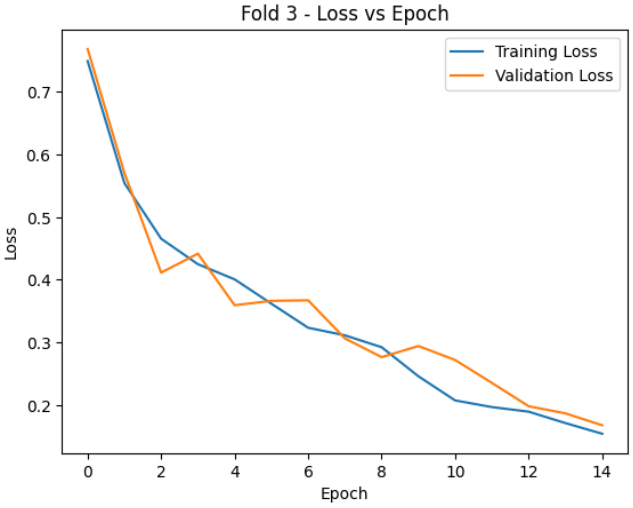

Fold 2 - ViT Receiver Operating Characteristic
True Positive Rate
False Positive Rate
ROC curve class Mild Impairment (area = 1.00)
ROC curve class Moderate Impairment (area = 1.00)
ROC curve class No Impairment (area = 0.99)
ROC curve class Very Mild Impairment (area = 0.99)

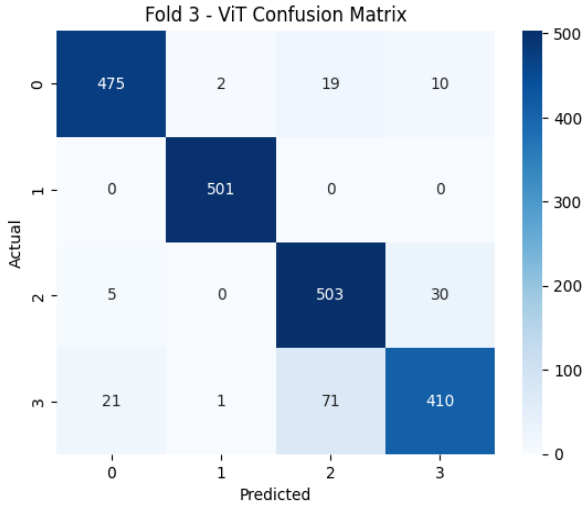




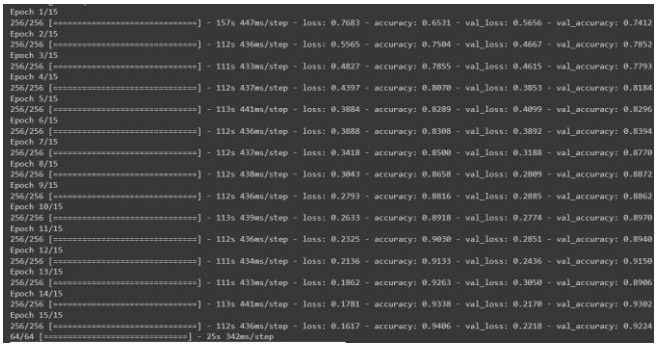
ViT Fold 3

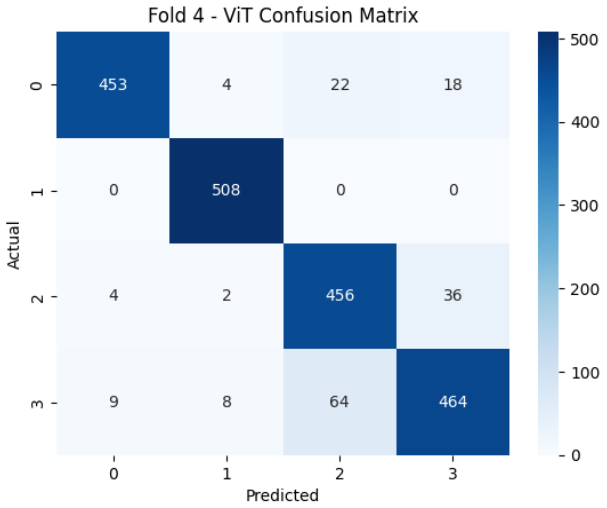




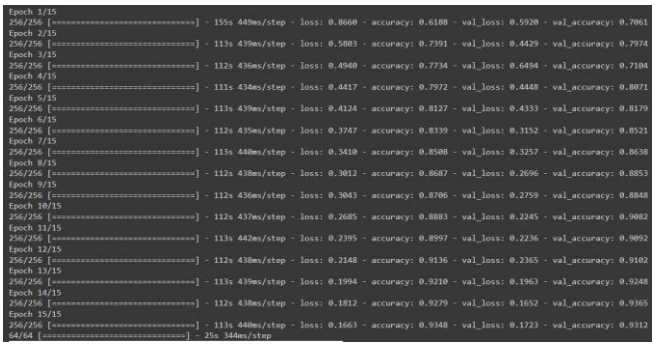


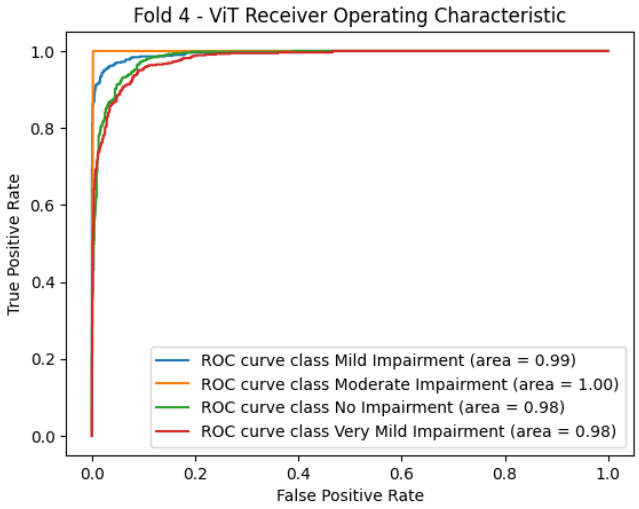
ViT Fold 4

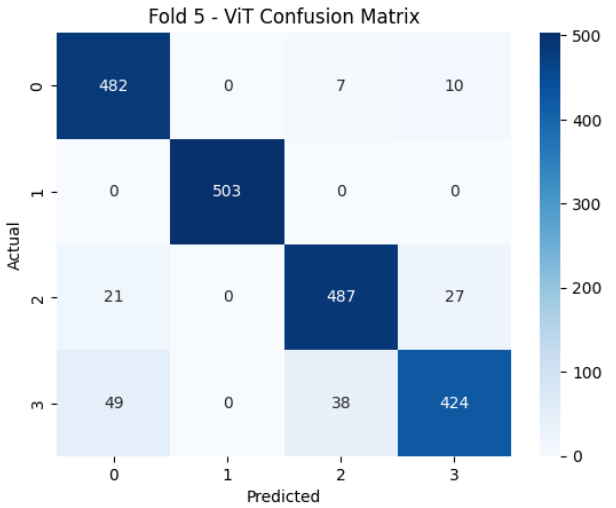


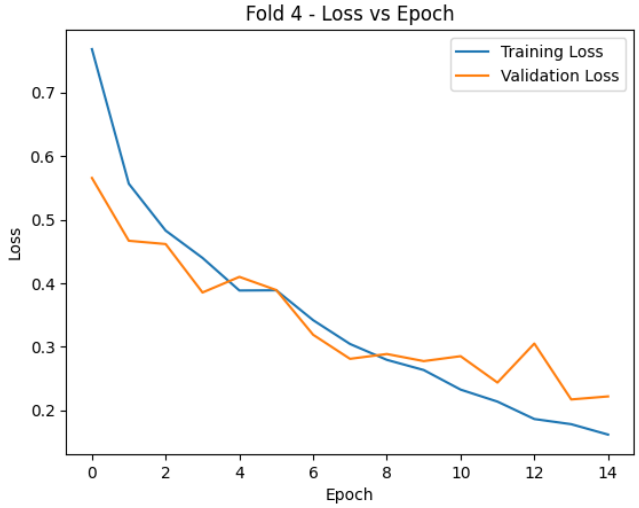

Fold 4 - ViT Confusion Matrix
Actual
Predicted
453
4
22
18
0
508
0
0
4
2
456
36
9
8
64
464

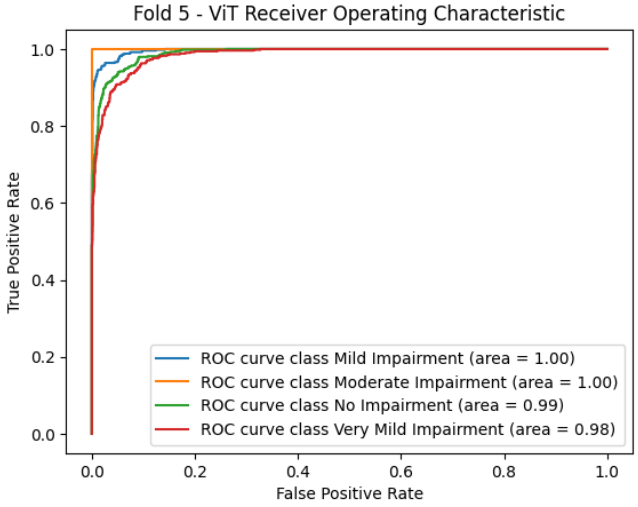
ViT Fold 5

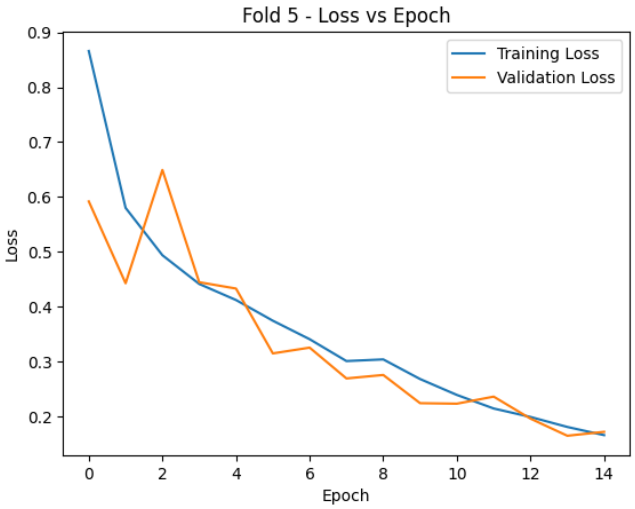

Epoch 1/15
256/256 [==========] - 155s 449ms/step - loss: 0.8660 - accuracy: 0.6188 - val_loss: 0.5920 - val_accuracy: 0.7061
Epoch 2/15
256/256 [==========] - 113s 439ms/step - loss: 0.5803 - accuracy: 0.7391 - val_loss: 0.4429 - val_accuracy: 0.7974
Epoch 3/15
256/256 [==========] - 112s 436ms/step - loss: 0.4940 - accuracy: 0.7734 - val_loss: 0.6494 - val_accuracy: 0.7104
Epoch 4/15
256/256 [==========] - 111s 434ms/step - loss: 0.4417 - accuracy: 0.7972 - val_loss: 0.4448 - val_accuracy: 0.8071
Epoch 5/15
256/256 [==========] - 113s 439ms/step - loss: 0.4124 - accuracy: 0.8127 - val_loss: 0.4333 - val_accuracy: 0.8179
Epoch 6/15
256/256 [==========] - 112s 435ms/step - loss: 0.3747 - accuracy: 0.8339 - val_loss: 0.3152 - val_accuracy: 0.8521
Epoch 7/15
256/256 [==========] - 113s 440ms/step - loss: 0.3410 - accuracy: 0.8508 - val_loss: 0.3257 - val_accuracy: 0.8638
Epoch 8/15
256/256 [==========] - 112s 438ms/step - loss: 0.3012 - accuracy: 0.8687 - val_loss: 0.2696 - val_accuracy: 0.8853
Epoch 9/15
256/256 [==========] - 112s 436ms/step - loss: 0.3043 - accuracy: 0.8706 - val_loss: 0.2759 - val_accuracy: 0.8848
Epoch 10/15
256/256 [==========] - 112s 437ms/step - loss: 0.2685 - accuracy: 0.8883 - val_loss: 0.2245 - val_accuracy: 0.9082
Epoch 11/15
256/256 [==========] - 113s 442ms/step - loss: 0.2395 - accuracy: 0.8997 - val_loss: 0.2236 - val_accuracy: 0.9092
Epoch 12/15
256/256 [==========] - 112s 438ms/step - loss: 0.2148 - accuracy: 0.9136 - val_loss: 0.2365 - val_accuracy: 0.9102
Epoch 13/15
256/256 [==========] - 113s 439ms/step - loss: 0.1994 - accuracy: 0.9210 - val_loss: 0.1963 - val_accuracy: 0.9248
Epoch 14/15
256/256 [==========] - 112s 438ms/step - loss: 0.1812 - accuracy: 0.9279 - val_loss: 0.1652 - val_accuracy: 0.9365
Epoch 15/15
256/256 [==========] - 113s 440ms/step - loss: 0.1663 - accuracy: 0.9348 - val_loss: 0.1723 - val_accuracy: 0.9312
64/64 [==========] - 25s 344ms/step

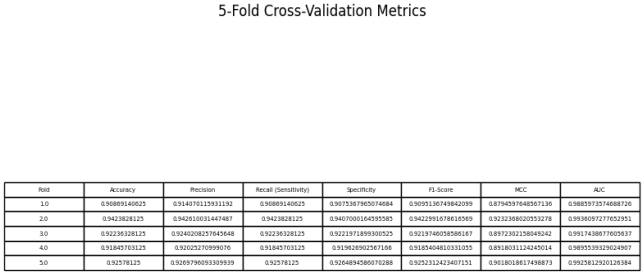

Fold 4 - ViT Receiver Operating Characteristic
True Positive Rate
False Positive Rate
ROC curve class Mild Impairment (area = 0.99)
ROC curve class Moderate Impairment (area = 1.00)
ROC curve class No Impairment (area = 0.98)
ROC curve class Very Mild Impairment (area = 0.98)


Fold 5 - ViT Confusion Matrix
Actual
Predicted
482
0
7
10
0
503
0
0
21
0
487
27
49
0
38
424


Fold 4 - Loss vs Epoch
Loss
Epoch
Training Loss
Validation Loss


Fold 5 - ViT Receiver Operating Characteristic
True Positive Rate
False Positive Rate
ROC curve class Mild Impairment (area = 1.00)
ROC curve class Moderate Impairment (area = 1.00)
ROC curve class No Impairment (area = 0.99)
ROC curve class Very Mild Impairment (area = 0.98)





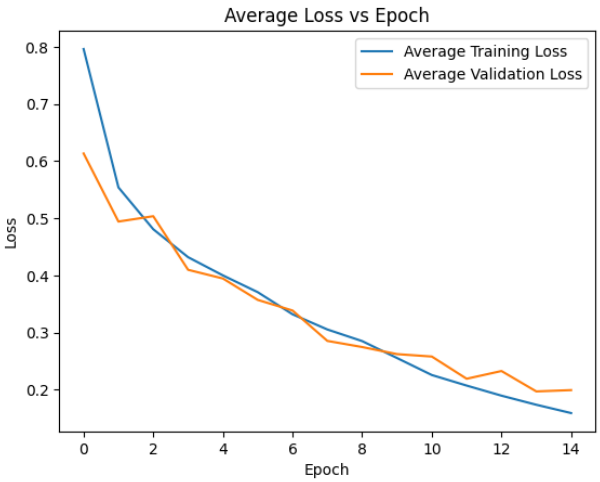
Fold	Accuracy	Precision	Recall (Sensitivity)	Specificity	F1-Score	MCC	AUC
1.0	0.95089140625	0.914707115931192	0.95089140625	0.9075367365074684	0.9095136749842099	0.8794357648567136	0.9885973574688726
2.0	0.9423828125	0.942610031447487	0.9423828125	0.9407000164595585	0.9422991678616569	0.9323368020553278	0.9938097277652951
3.0	0.92236328125	0.9240208257645648	0.92236328125	0.9221971899300525	0.9219746058586167	0.8972302158049242	0.9917438877605837
4.0	0.91845703125	0.9202527099907 6	0.91845703125	0.919626902567166	0.9185404810331055	0.8918031124245014	0.9895539329024907
5.0	0.925781 25	0.9269796093309939	0.925781 25	0.9264894586070288	0.9252312423407151	0.9010818617498873	0.9925812920126384

ViT Genel Model Sonuçları

5-Fold Cross-Validation Average Metrics:

Fold	3.000000
Accuracy	0.923535
Precision	0.925587
Recall (Sensitivity)	0.923535
Specificity	0.923310
F1-Score	0.923512
MCC	0.898706
AUC	0.991217

dtype: float64



Tabloların Detaylı ve Net Bir Şekilde İncelenmesi:

Fold 1

Metric	Value
Accuracy	0.95089140263
Precision	0.914707119531192
Recall	0.95089140263
Specificity	0.9707339765074684
F1-Score	0.9509136749842099
MCC	0.8794357648367136
AUC	0.9888793774688726

Fold 2

Metric	Value
Accuracy	0.9432282123
Precision	0.94261001347487
Recall	0.9432282123
Specificity	0.940700016495935
F1-Score	0.9422916076816055
MCC	0.932328608153378
AUC	0.953097707625291

Fold 3

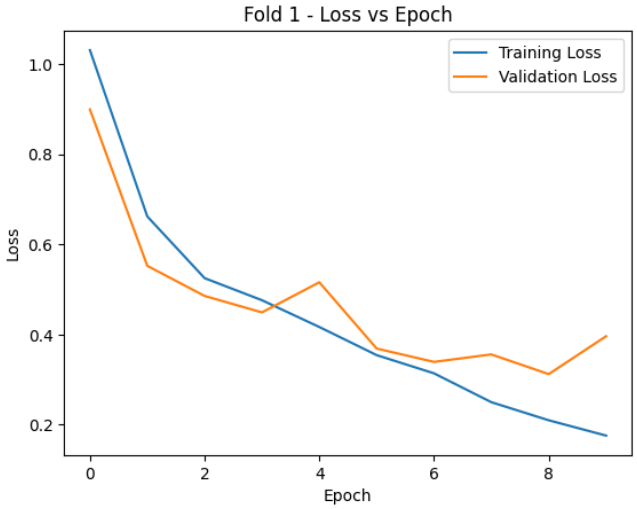
Metric	Value
Accuracy	0.92326382125
Precision	0.924020287654648
Recall	0.92326382125
Specificity	0.922719188930025
F1-Score	0.92197405988167
MCC	0.897732012869422
AUC	0.99143877606367

Fold 4

Metric	Value
Accuracy	0.91548730125
Precision	0.92053270979096
Recall	0.91548730125
Specificity	0.92196205927616
F1-Score	0.915840148031105
MCC	0.891308124249014
AUC	0.985935329024907

Fold 5

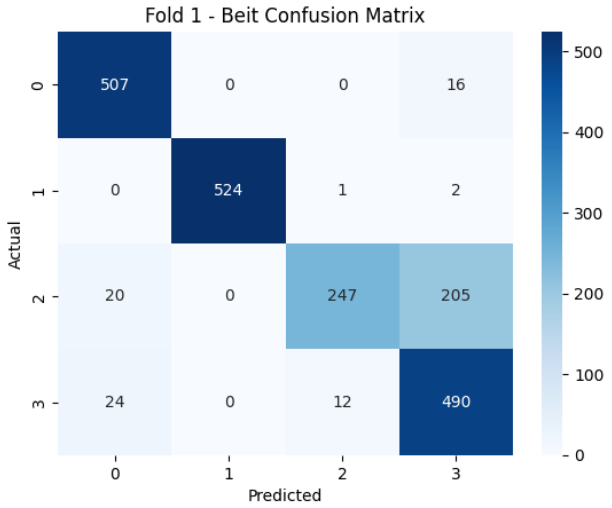
Metric	Value
Accuracy	0.92378125
Precision	0.920979603930939
Recall	0.92378125
Specificity	0.926489436070288
F1-Score	0.92332142340711
MCC	0.901801817498873
AUC	0.992581292012384

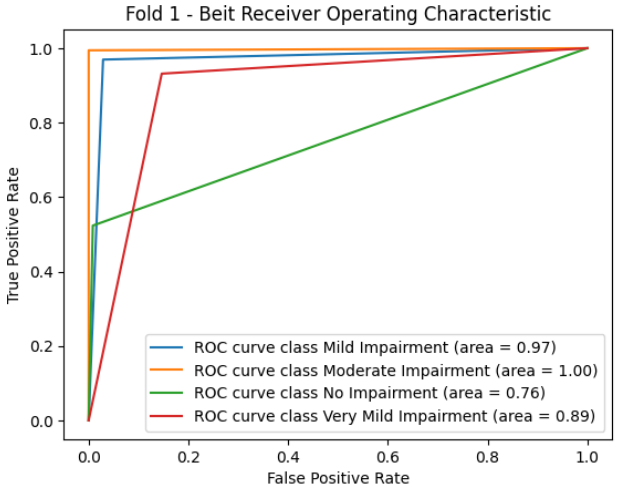


Microsoft BeiT

BeiT Fold 1

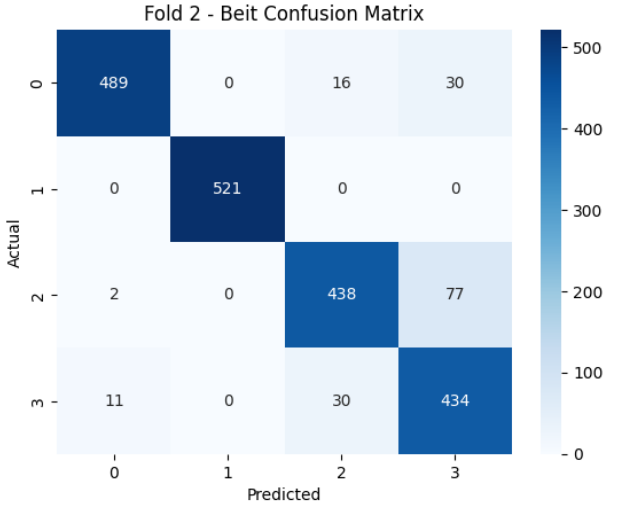
```
Epoch 1/10, Train Loss: 0.6717, Val Loss: 0.5627, Val Accuracy: 0.7407
Epoch 2/10, Train Loss: 0.4874, Val Loss: 0.4730, Val Accuracy: 0.7754
Epoch 3/10, Train Loss: 0.4007, Val Loss: 0.4341, Val Accuracy: 0.8159
Epoch 4/10, Train Loss: 0.3590, Val Loss: 0.3016, Val Accuracy: 0.8716
Epoch 5/10, Train Loss: 0.2977, Val Loss: 0.3021, Val Accuracy: 0.8657
Epoch 6/10, Train Loss: 0.2508, Val Loss: 0.2528, Val Accuracy: 0.8931
Epoch 7/10, Train Loss: 0.2099, Val Loss: 0.2082, Val Accuracy: 0.9150
Epoch 8/10, Train Loss: 0.1754, Val Loss: 0.1873, Val Accuracy: 0.9170
Epoch 9/10, Train Loss: 0.1541, Val Loss: 0.1549, Val Accuracy: 0.9360
Epoch 10/10, Train Loss: 0.1205, Val Loss: 0.1486, Val Accuracy: 0.9448
```

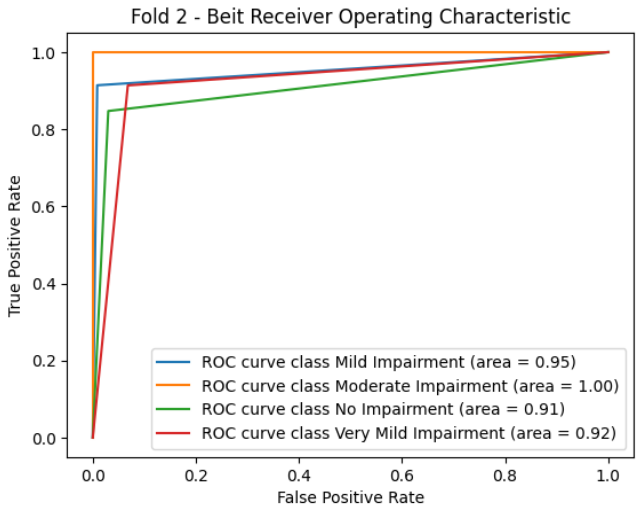


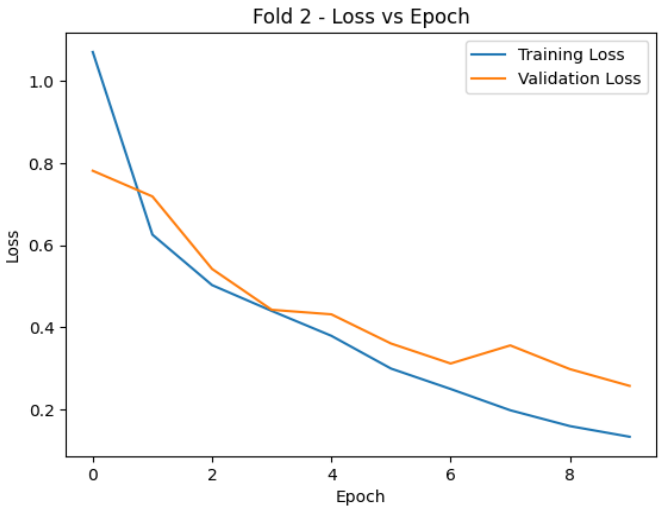


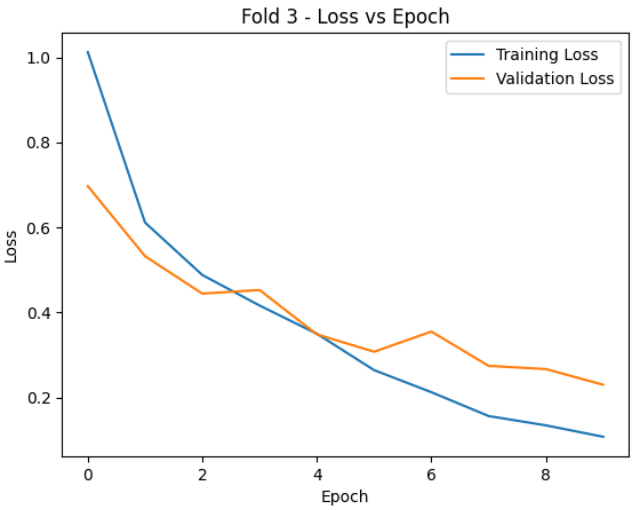
BeiT Fold 2

```
Epoch 1/10, Train Loss: 0.6540, Val Loss: 0.4680, Val Accuracy: 0.7935
Epoch 2/10, Train Loss: 0.4431, Val Loss: 0.4017, Val Accuracy: 0.8145
Epoch 3/10, Train Loss: 0.3709, Val Loss: 0.3439, Val Accuracy: 0.8340
Epoch 4/10, Train Loss: 0.3240, Val Loss: 0.3434, Val Accuracy: 0.8418
Epoch 5/10, Train Loss: 0.2565, Val Loss: 0.2715, Val Accuracy: 0.8789
Epoch 6/10, Train Loss: 0.2054, Val Loss: 0.1934, Val Accuracy: 0.9204
Epoch 7/10, Train Loss: 0.1686, Val Loss: 0.1732, Val Accuracy: 0.9312
Epoch 8/10, Train Loss: 0.1293, Val Loss: 0.1339, Val Accuracy: 0.9443
Epoch 9/10, Train Loss: 0.1136, Val Loss: 0.2264, Val Accuracy: 0.9199
Epoch 10/10, Train Loss: 0.0988, Val Loss: 0.1299, Val Accuracy: 0.9531
```







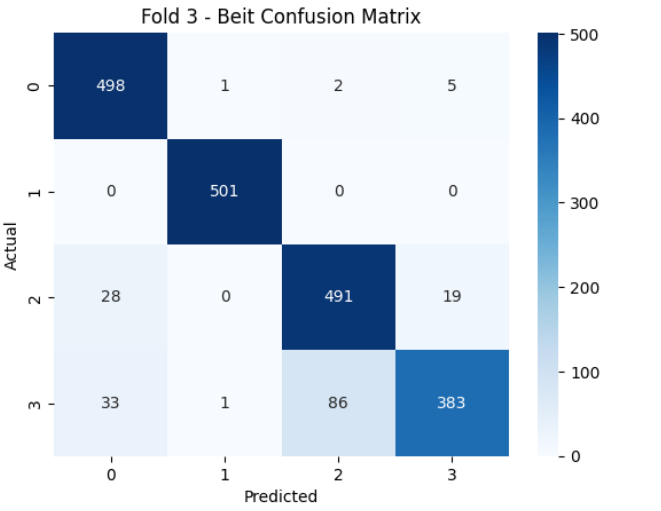


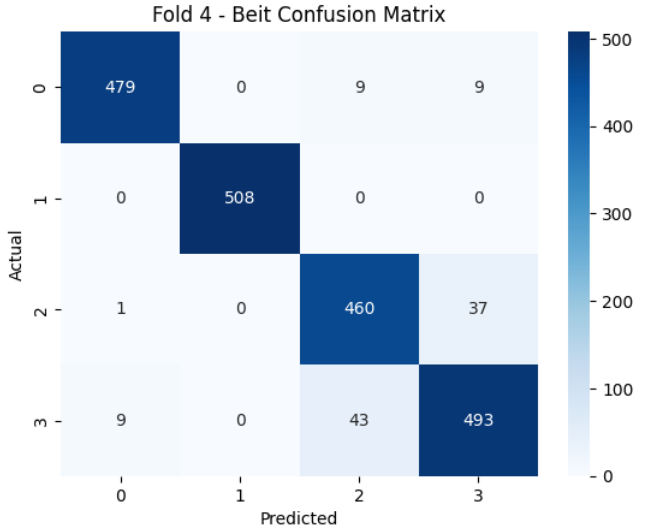
BeiT Fold 3

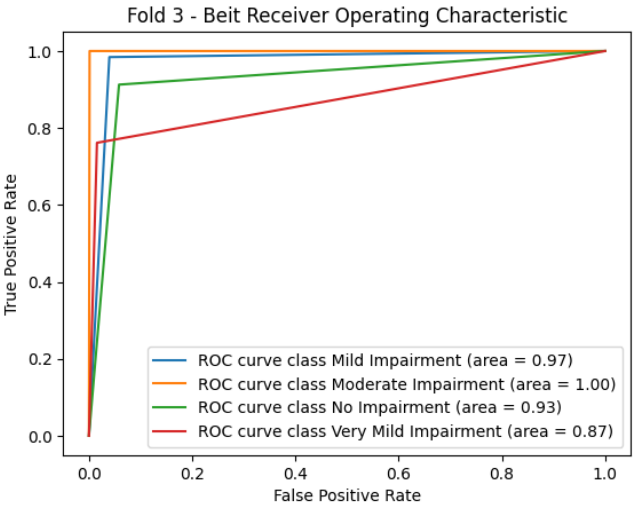
BeiT Fold 4

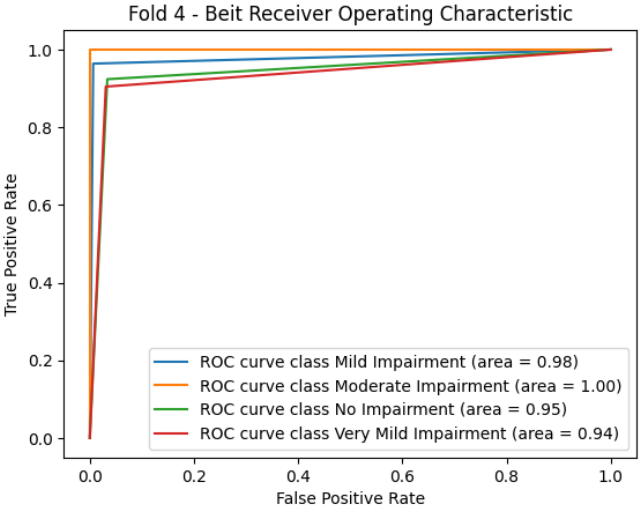
```
Epoch 1/10, Train Loss: 0.7025, Val Loss: 0.5054, Val Accuracy: 0.7656
Epoch 2/10, Train Loss: 0.4689, Val Loss: 0.4013, Val Accuracy: 0.8096
Epoch 3/10, Train Loss: 0.3921, Val Loss: 0.3913, Val Accuracy: 0.8345
Epoch 4/10, Train Loss: 0.3388, Val Loss: 0.3061, Val Accuracy: 0.8594
Epoch 5/10, Train Loss: 0.2895, Val Loss: 0.3207, Val Accuracy: 0.8687
Epoch 6/10, Train Loss: 0.2610, Val Loss: 0.2828, Val Accuracy: 0.8823
Epoch 7/10, Train Loss: 0.2147, Val Loss: 0.3065, Val Accuracy: 0.8789
Epoch 8/10, Train Loss: 0.1771, Val Loss: 0.2076, Val Accuracy: 0.9170
Epoch 9/10, Train Loss: 0.1435, Val Loss: 0.1476, Val Accuracy: 0.9414
Epoch 10/10, Train Loss: 0.1217, Val Loss: 0.1604, Val Accuracy: 0.9355
```

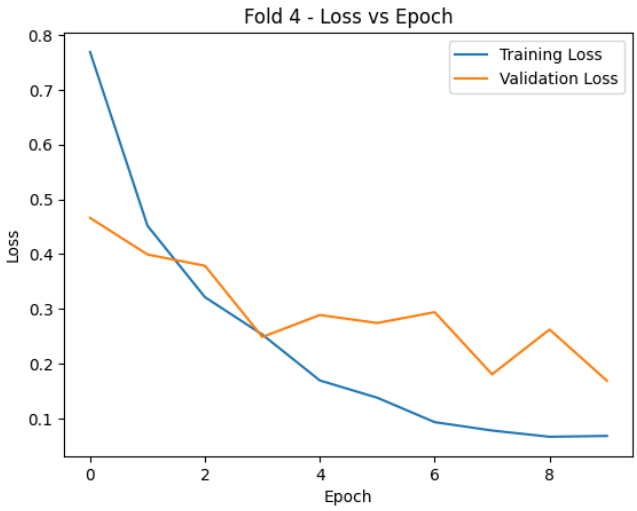
```
Epoch 1/10, Train Loss: 0.6381, Val Loss: 0.4718, Val Accuracy: 0.8027
Epoch 2/10, Train Loss: 0.4203, Val Loss: 0.3926, Val Accuracy: 0.8262
Epoch 3/10, Train Loss: 0.3601, Val Loss: 0.3369, Val Accuracy: 0.8657
Epoch 4/10, Train Loss: 0.2950, Val Loss: 0.3071, Val Accuracy: 0.8765
Epoch 5/10, Train Loss: 0.2438, Val Loss: 0.2609, Val Accuracy: 0.8945
Epoch 6/10, Train Loss: 0.1937, Val Loss: 0.1929, Val Accuracy: 0.9258
Epoch 7/10, Train Loss: 0.1676, Val Loss: 0.2245, Val Accuracy: 0.9111
Epoch 8/10, Train Loss: 0.1296, Val Loss: 0.1474, Val Accuracy: 0.9438
Epoch 9/10, Train Loss: 0.1131, Val Loss: 0.1299, Val Accuracy: 0.9478
Epoch 10/10, Train Loss: 0.1104, Val Loss: 0.1511, Val Accuracy: 0.9419
```

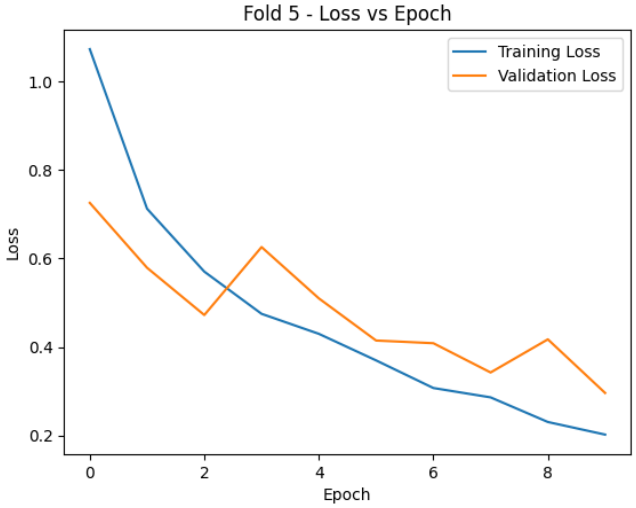






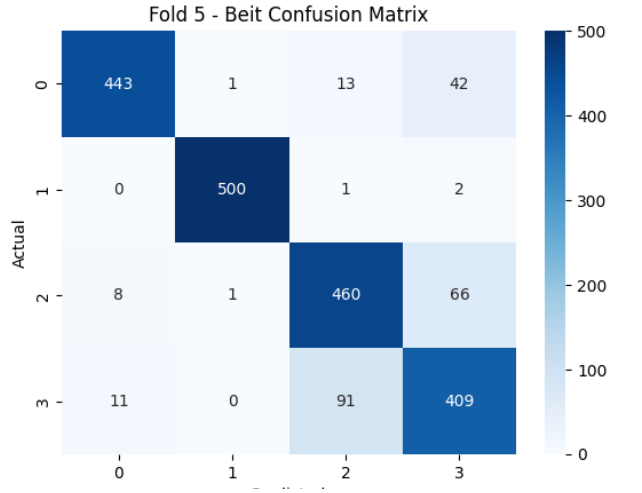


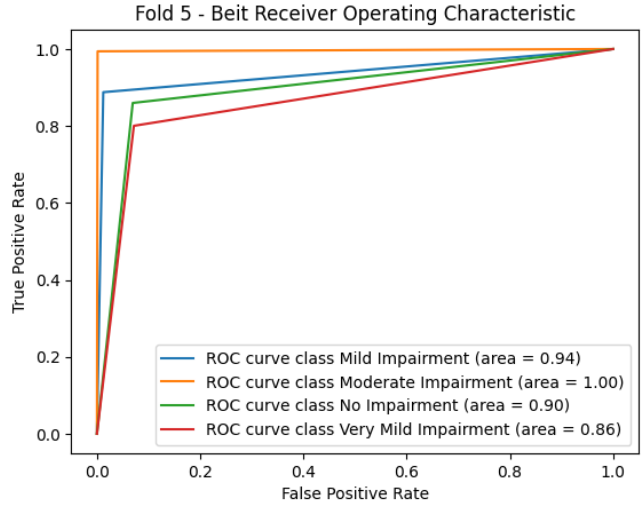




BeiT Fold 5

```
Epoch 1/10, Train Loss: 0.6573, Val Loss: 0.5074, Val Accuracy: 0.7549
Epoch 2/10, Train Loss: 0.4401, Val Loss: 0.4136, Val Accuracy: 0.7959
Epoch 3/10, Train Loss: 0.3697, Val Loss: 0.3388, Val Accuracy: 0.8530
Epoch 4/10, Train Loss: 0.3093, Val Loss: 0.3031, Val Accuracy: 0.8755
Epoch 5/10, Train Loss: 0.2604, Val Loss: 0.2549, Val Accuracy: 0.8936
Epoch 6/10, Train Loss: 0.2115, Val Loss: 0.2313, Val Accuracy: 0.9023
Epoch 7/10, Train Loss: 0.1784, Val Loss: 0.2850, Val Accuracy: 0.8979
Epoch 8/10, Train Loss: 0.1416, Val Loss: 0.1890, Val Accuracy: 0.9282
Epoch 9/10, Train Loss: 0.1266, Val Loss: 0.1928, Val Accuracy: 0.9238
Epoch 10/10, Train Loss: 0.1088, Val Loss: 0.1399, Val Accuracy: 0.9463
```



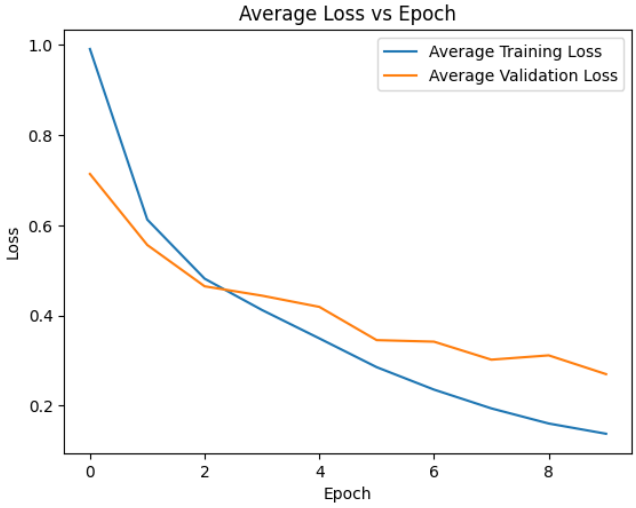


BeiT Genel Model Sonuçları

5-Fold Cross-Validation Average Metrics:

Fold	3.000000
Accuracy	0.905762
Precision	0.912797
Recall (Sensitivity)	0.905762
Specificity	0.904291
F1-Score	0.904428
MCC	0.876959
AUC	0.936394

dtype: float64



5-Fold Cross-Validation Metrics

Fold	Accuracy	Precision	Recall (Sensitivity)	Specificity	F1-Score	MCC	AUC
1.0	0.86328125	0.8877551809966195	0.86328125	0.8546446715652163	0.8563762490890070	0.8277001725052165	0.9043699695579965
2.0	0.9189453125	0.9233704390266402	0.9189453125	0.9187245649871891	0.9196280670818023	0.8929007776175146	0.9460296813835309
3.0	0.91455078125	0.9176572237101864	0.91455078125	0.9145651350138586	0.9128910681963016	0.8879165988455165	0.9429495718360155
4.0	0.947265625	0.9476299885003876	0.947265625	0.9480161578142077	0.9473823019533052	0.9297032632559575	0.9651629168693617
5.0	0.884765625	0.8875708791769135	0.884765625	0.8855039524837774	0.8856599366847909	0.846573257090991	0.9234360997471923

Tabloların Detaylı ve Net Bir Şekilde İncelenmesi:

Fold 1

Metric	Value
Accuracy	0.9448421875
Precision	0.94857306880307
Recall	0.9448421875
Specificity	0.942160601203459
F1-Score	0.944896747805859
MCC	0.875739534724215
AUC	0.961851226708138

Fold 2

Metric	Value
Accuracy	0.935125
Precision	0.9576011268252341
Recall	0.935125
Specificity	0.953469058073064
F1-Score	0.935701714100284
MCC	0.938719010231785
AUC	0.969151105798268

Fold 3

Metric	Value
Accuracy	0.935546875
Precision	0.938002733064748
Recall	0.935546875
Specificity	0.935534456147233
F1-Score	0.936028972052253
MCC	0.914478928013252
AUC	0.956097180612542

Fold 4

Metric	Value
Accuracy	0.9458984375
Precision	0.943911249577125
Recall	0.9458984375
Specificity	0.941236405494228
F1-Score	0.9439123873912812
MCC	0.923159001246043
AUC	0.950683045078787

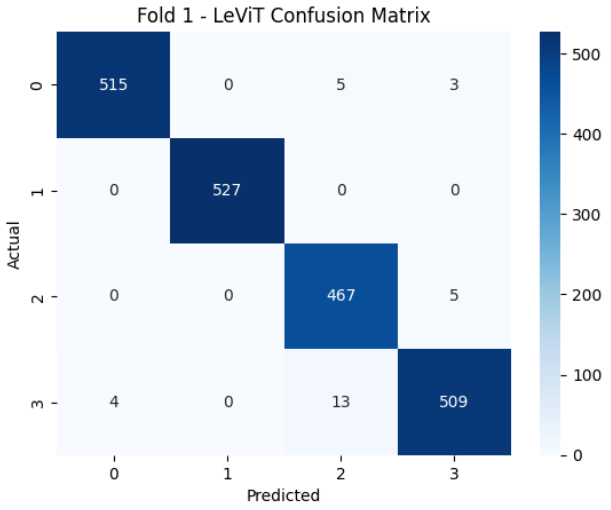
Fold 5

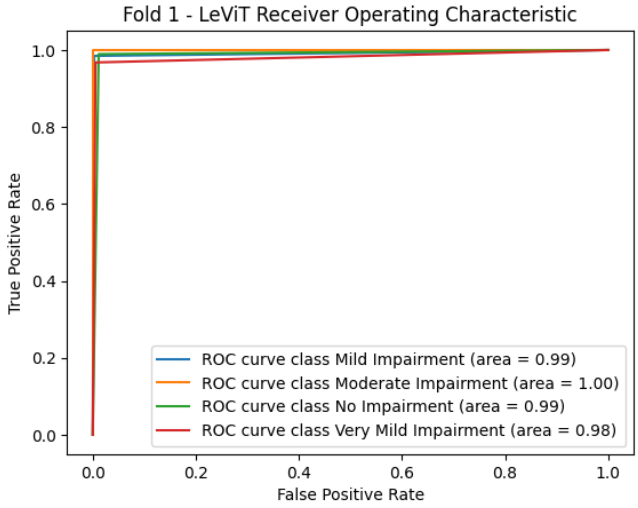
Metric	Value
Accuracy	0.9462890625
Precision	0.9467119743020672
Recall	0.9462890625
Specificity	0.9472202389457377
F1-Score	0.9463721833024769
MCC	0.928467597882028
AUC	0.9464327480097336

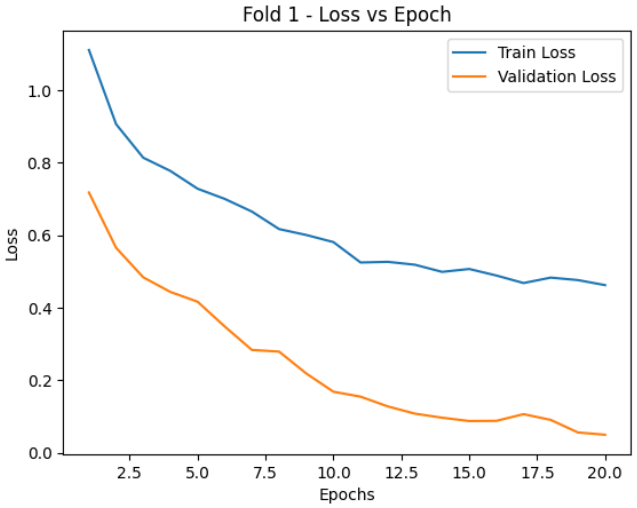
LeViT

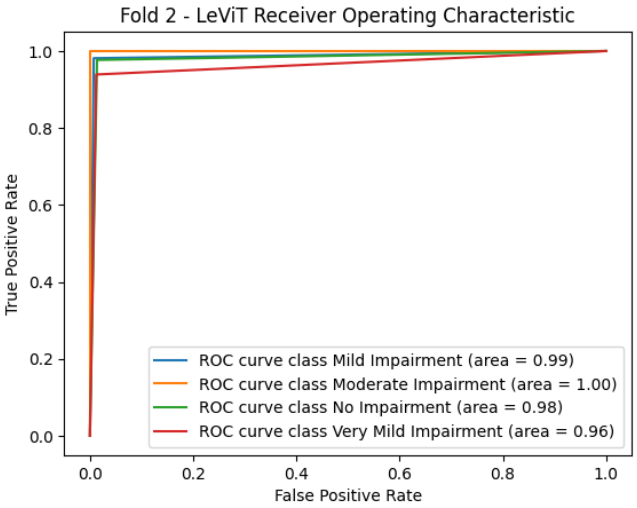
LeViT Fold 1

```
Epoch 1/20, Train Loss: 1.1114, Val Loss: 0.7183, Val Accuracy: 0.7104
Epoch 2/20, Train Loss: 0.9068, Val Loss: 0.5657, Val Accuracy: 0.7920
Epoch 3/20, Train Loss: 0.8142, Val Loss: 0.4843, Val Accuracy: 0.8267
Epoch 4/20, Train Loss: 0.7777, Val Loss: 0.4439, Val Accuracy: 0.8350
Epoch 5/20, Train Loss: 0.7287, Val Loss: 0.4169, Val Accuracy: 0.8457
Epoch 6/20, Train Loss: 0.7006, Val Loss: 0.3485, Val Accuracy: 0.8711
Epoch 7/20, Train Loss: 0.6656, Val Loss: 0.2838, Val Accuracy: 0.9043
Epoch 8/20, Train Loss: 0.6173, Val Loss: 0.2793, Val Accuracy: 0.8906
Epoch 9/20, Train Loss: 0.6010, Val Loss: 0.2190, Val Accuracy: 0.9224
Epoch 10/20, Train Loss: 0.5814, Val Loss: 0.1686, Val Accuracy: 0.9492
Epoch 11/20, Train Loss: 0.5251, Val Loss: 0.1550, Val Accuracy: 0.9497
Epoch 12/20, Train Loss: 0.5269, Val Loss: 0.1281, Val Accuracy: 0.9580
Epoch 13/20, Train Loss: 0.5190, Val Loss: 0.1081, Val Accuracy: 0.9658
Epoch 14/20, Train Loss: 0.4992, Val Loss: 0.0969, Val Accuracy: 0.9683
Epoch 15/20, Train Loss: 0.5072, Val Loss: 0.0877, Val Accuracy: 0.9741
Epoch 16/20, Train Loss: 0.4892, Val Loss: 0.0882, Val Accuracy: 0.9746
Epoch 17/20, Train Loss: 0.4684, Val Loss: 0.1067, Val Accuracy: 0.9614
Epoch 18/20, Train Loss: 0.4834, Val Loss: 0.0909, Val Accuracy: 0.9697
Epoch 19/20, Train Loss: 0.4766, Val Loss: 0.0562, Val Accuracy: 0.9824
Epoch 20/20, Train Loss: 0.4627, Val Loss: 0.0499, Val Accuracy: 0.9854
```



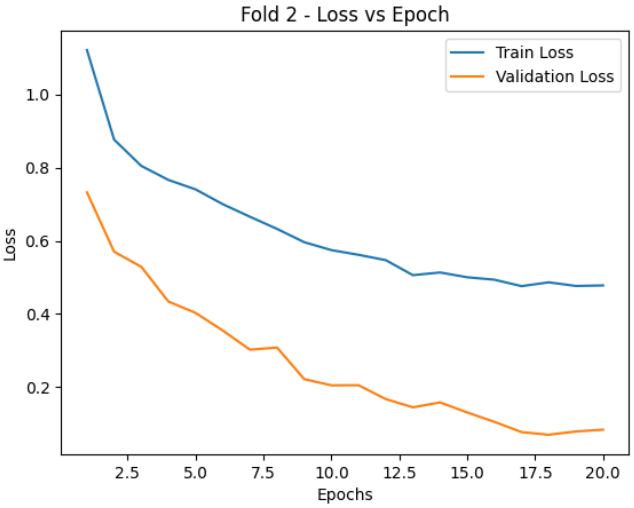


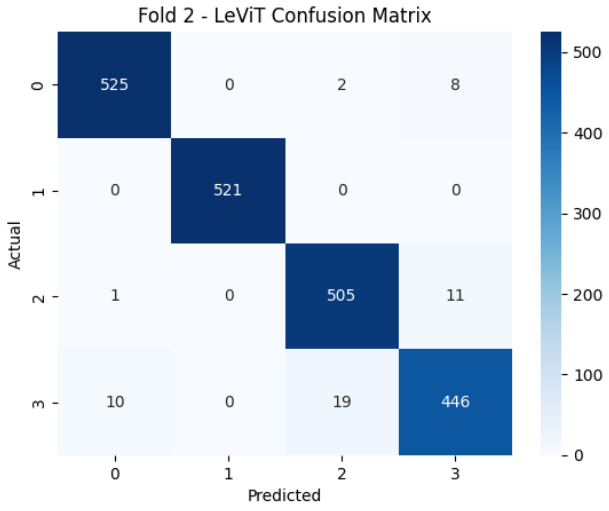




LeViT Fold 2

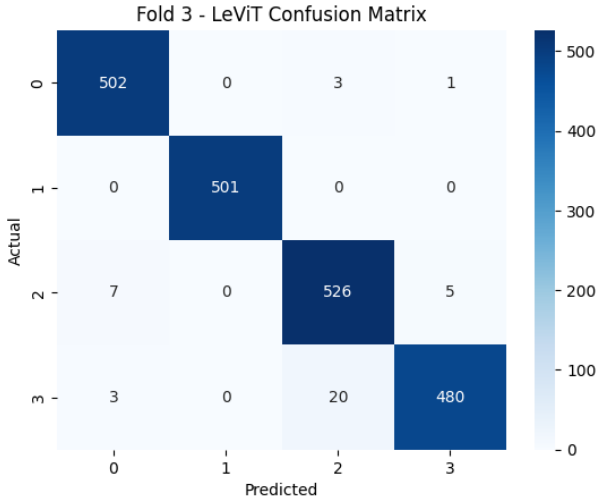
```
Epoch 1/20, Train Loss: 1.1216, Val Loss: 0.7327, Val Accuracy: 0.7104
Epoch 2/20, Train Loss: 0.8767, Val Loss: 0.5702, Val Accuracy: 0.7754
Epoch 3/20, Train Loss: 0.8048, Val Loss: 0.5289, Val Accuracy: 0.8022
Epoch 4/20, Train Loss: 0.7664, Val Loss: 0.4338, Val Accuracy: 0.8291
Epoch 5/20, Train Loss: 0.7406, Val Loss: 0.4029, Val Accuracy: 0.8389
Epoch 6/20, Train Loss: 0.7001, Val Loss: 0.3547, Val Accuracy: 0.8701
Epoch 7/20, Train Loss: 0.6658, Val Loss: 0.3023, Val Accuracy: 0.8926
Epoch 8/20, Train Loss: 0.6325, Val Loss: 0.3081, Val Accuracy: 0.8901
Epoch 9/20, Train Loss: 0.5962, Val Loss: 0.2218, Val Accuracy: 0.9238
Epoch 10/20, Train Loss: 0.5745, Val Loss: 0.2048, Val Accuracy: 0.9316
Epoch 11/20, Train Loss: 0.5617, Val Loss: 0.2051, Val Accuracy: 0.9263
Epoch 12/20, Train Loss: 0.5471, Val Loss: 0.1672, Val Accuracy: 0.9443
Epoch 13/20, Train Loss: 0.5060, Val Loss: 0.1446, Val Accuracy: 0.9521
Epoch 14/20, Train Loss: 0.5134, Val Loss: 0.1581, Val Accuracy: 0.9424
Epoch 15/20, Train Loss: 0.5003, Val Loss: 0.1306, Val Accuracy: 0.9604
Epoch 16/20, Train Loss: 0.4936, Val Loss: 0.1050, Val Accuracy: 0.9673
Epoch 17/20, Train Loss: 0.4760, Val Loss: 0.0769, Val Accuracy: 0.9771
Epoch 18/20, Train Loss: 0.4865, Val Loss: 0.0697, Val Accuracy: 0.9819
Epoch 19/20, Train Loss: 0.4765, Val Loss: 0.0786, Val Accuracy: 0.9731
Epoch 20/20, Train Loss: 0.4780, Val Loss: 0.0836, Val Accuracy: 0.9751
```





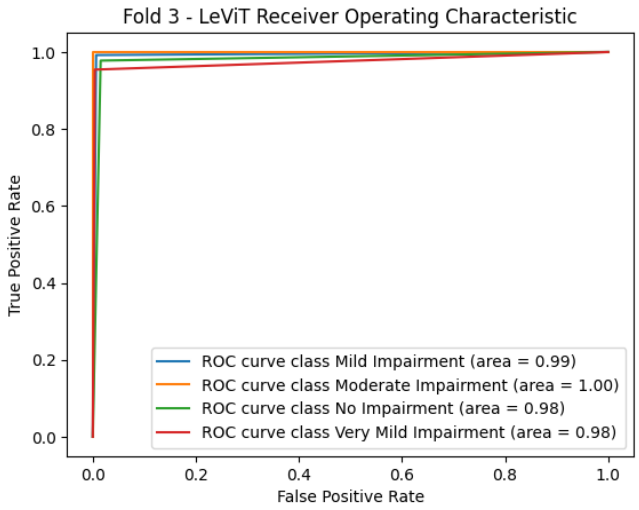
LeViT Fold 3

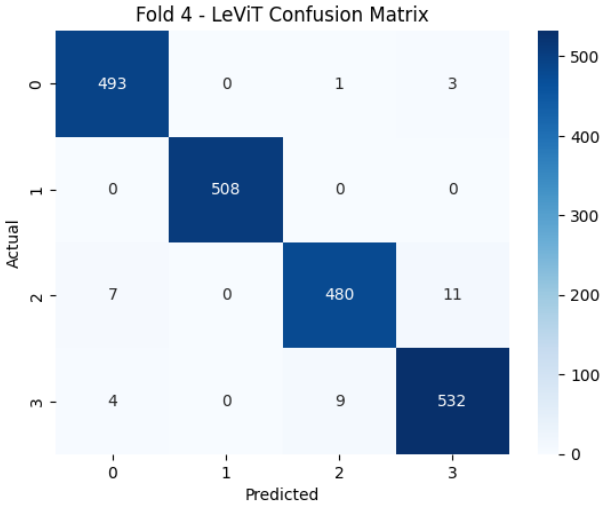
```
Epoch 1/20, Train Loss: 1.1409, Val Loss: 2.3517, Val Accuracy: 0.6963
Epoch 2/20, Train Loss: 0.9123, Val Loss: 0.5948, Val Accuracy: 0.7769
Epoch 3/20, Train Loss: 0.8430, Val Loss: 0.5341, Val Accuracy: 0.8022
Epoch 4/20, Train Loss: 0.7856, Val Loss: 0.4555, Val Accuracy: 0.8296
Epoch 5/20, Train Loss: 0.7575, Val Loss: 0.4434, Val Accuracy: 0.8257
Epoch 6/20, Train Loss: 0.7241, Val Loss: 0.4320, Val Accuracy: 0.8394
Epoch 7/20, Train Loss: 0.6991, Val Loss: 0.3600, Val Accuracy: 0.8599
Epoch 8/20, Train Loss: 0.6735, Val Loss: 0.3417, Val Accuracy: 0.8721
Epoch 9/20, Train Loss: 0.6377, Val Loss: 0.2575, Val Accuracy: 0.9072
Epoch 10/20, Train Loss: 0.5926, Val Loss: 0.2309, Val Accuracy: 0.9126
Epoch 11/20, Train Loss: 0.5811, Val Loss: 0.1730, Val Accuracy: 0.9526
Epoch 12/20, Train Loss: 0.5458, Val Loss: 0.1608, Val Accuracy: 0.9395
Epoch 13/20, Train Loss: 0.5286, Val Loss: 0.1382, Val Accuracy: 0.9556
Epoch 14/20, Train Loss: 0.5155, Val Loss: 0.1190, Val Accuracy: 0.9653
Epoch 15/20, Train Loss: 0.4962, Val Loss: 0.1144, Val Accuracy: 0.9614
Epoch 16/20, Train Loss: 0.4791, Val Loss: 0.1002, Val Accuracy: 0.9634
Epoch 17/20, Train Loss: 0.4887, Val Loss: 0.0878, Val Accuracy: 0.9731
Epoch 18/20, Train Loss: 0.4735, Val Loss: 0.1140, Val Accuracy: 0.9624
Epoch 19/20, Train Loss: 0.4683, Val Loss: 0.1641, Val Accuracy: 0.9614
Epoch 20/20, Train Loss: 0.4808, Val Loss: 0.0696, Val Accuracy: 0.9810
```

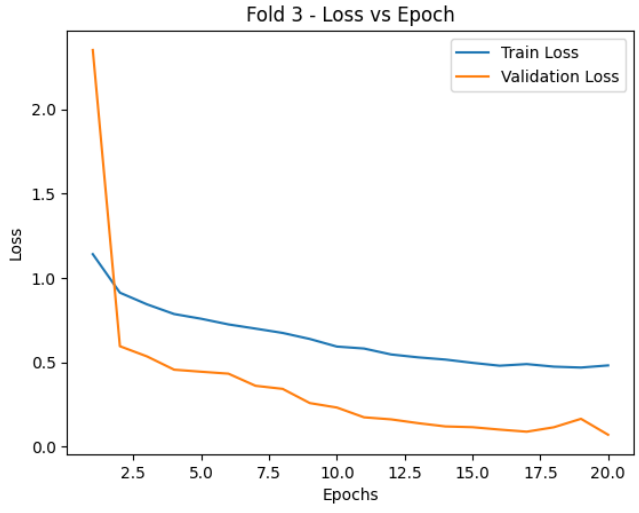


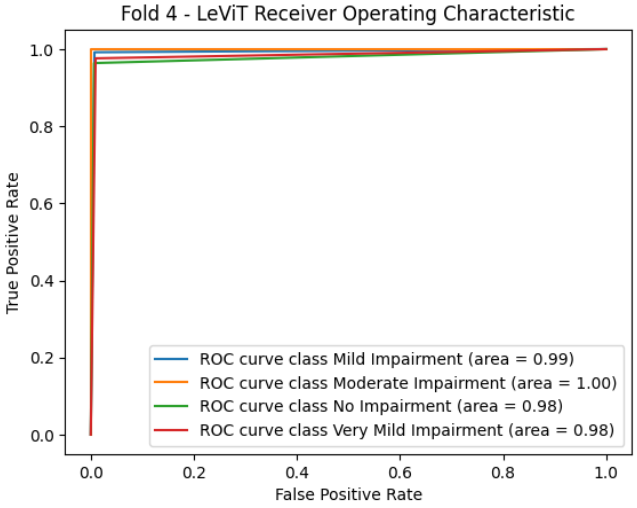
LeViT Fold 4

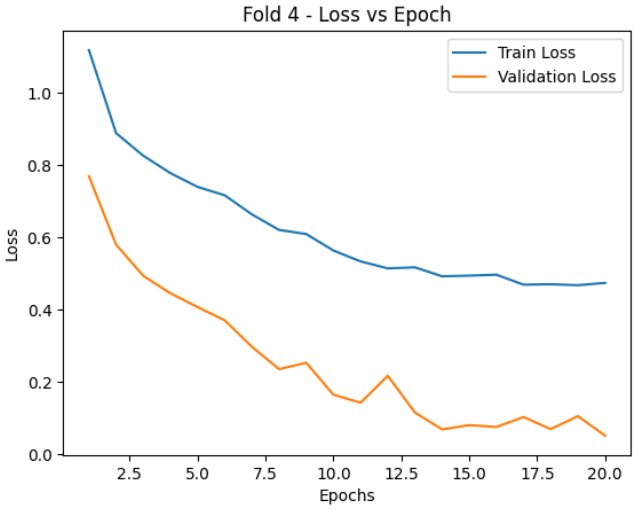
```
Epoch 1/20, Train Loss: 1.1172, Val Loss: 0.7686, Val Accuracy: 0.7280
Epoch 2/20, Train Loss: 0.8877, Val Loss: 0.5796, Val Accuracy: 0.7773
Epoch 3/20, Train Loss: 0.8254, Val Loss: 0.4933, Val Accuracy: 0.8091
Epoch 4/20, Train Loss: 0.7772, Val Loss: 0.4451, Val Accuracy: 0.8325
Epoch 5/20, Train Loss: 0.7391, Val Loss: 0.4070, Val Accuracy: 0.8501
Epoch 6/20, Train Loss: 0.7159, Val Loss: 0.3702, Val Accuracy: 0.8770
Epoch 7/20, Train Loss: 0.6631, Val Loss: 0.2973, Val Accuracy: 0.8911
Epoch 8/20, Train Loss: 0.6202, Val Loss: 0.2355, Val Accuracy: 0.9214
Epoch 9/20, Train Loss: 0.6088, Val Loss: 0.2531, Val Accuracy: 0.9160
Epoch 10/20, Train Loss: 0.5633, Val Loss: 0.1649, Val Accuracy: 0.9399
Epoch 11/20, Train Loss: 0.5333, Val Loss: 0.1424, Val Accuracy: 0.9561
Epoch 12/20, Train Loss: 0.5140, Val Loss: 0.2170, Val Accuracy: 0.9189
Epoch 13/20, Train Loss: 0.5168, Val Loss: 0.1156, Val Accuracy: 0.9629
Epoch 14/20, Train Loss: 0.4921, Val Loss: 0.0687, Val Accuracy: 0.9819
Epoch 15/20, Train Loss: 0.4939, Val Loss: 0.0806, Val Accuracy: 0.9766
Epoch 16/20, Train Loss: 0.4964, Val Loss: 0.0755, Val Accuracy: 0.9766
Epoch 17/20, Train Loss: 0.4690, Val Loss: 0.1030, Val Accuracy: 0.9639
Epoch 18/20, Train Loss: 0.4701, Val Loss: 0.0696, Val Accuracy: 0.9814
Epoch 19/20, Train Loss: 0.4675, Val Loss: 0.1055, Val Accuracy: 0.9629
Epoch 20/20, Train Loss: 0.4738, Val Loss: 0.0517, Val Accuracy: 0.9829
```

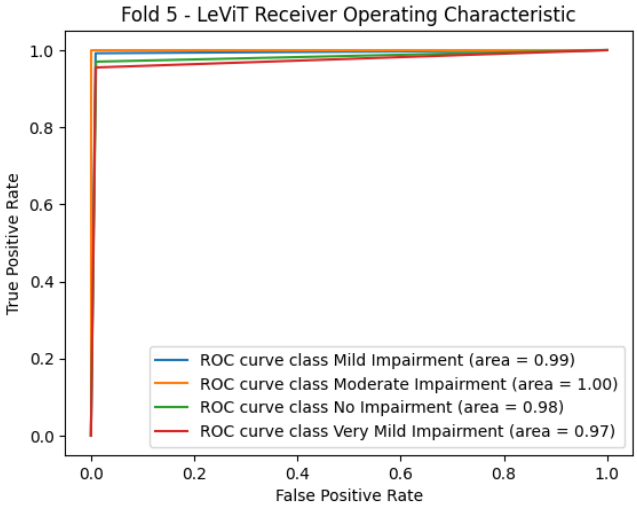








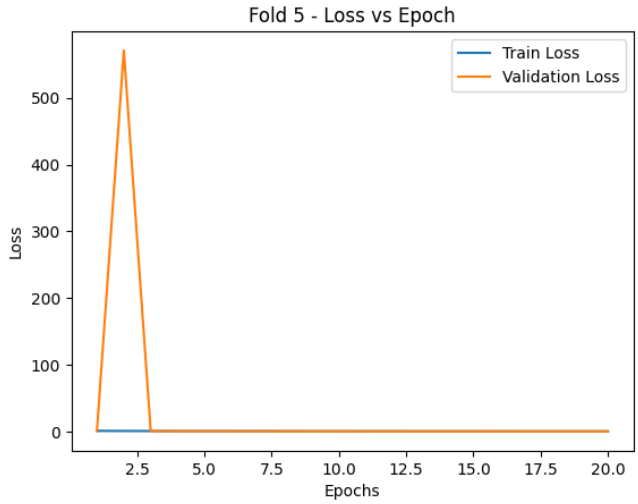


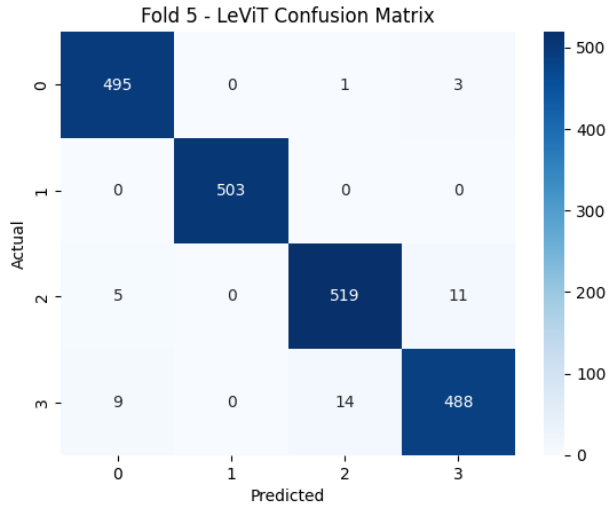


LeViT Fold 5

```
Epoch 1/20, Train Loss: 1.1220, Val Loss: 0.7385, Val Accuracy: 0.7373
Epoch 2/20, Train Loss: 0.8938, Val Loss: 570.9335, Val Accuracy: 0.4248
Epoch 3/20, Train Loss: 0.8275, Val Loss: 0.6047, Val Accuracy: 0.8101
Epoch 4/20, Train Loss: 0.7752, Val Loss: 0.4893, Val Accuracy: 0.8086
Epoch 5/20, Train Loss: 0.7319, Val Loss: 0.3969, Val Accuracy: 0.8462
Epoch 6/20, Train Loss: 0.6955, Val Loss: 0.3485, Val Accuracy: 0.8750
Epoch 7/20, Train Loss: 0.6670, Val Loss: 0.3540, Val Accuracy: 0.8755
Epoch 8/20, Train Loss: 0.6331, Val Loss: 0.2579, Val Accuracy: 0.9097
Epoch 9/20, Train Loss: 0.5850, Val Loss: 0.2841, Val Accuracy: 0.8901
Epoch 10/20, Train Loss: 0.5682, Val Loss: 0.2068, Val Accuracy: 0.9302
Epoch 11/20, Train Loss: 0.5354, Val Loss: 0.1450, Val Accuracy: 0.9541
Epoch 12/20, Train Loss: 0.5327, Val Loss: 0.1427, Val Accuracy: 0.9531
Epoch 13/20, Train Loss: 0.5055, Val Loss: 0.1183, Val Accuracy: 0.9619
Epoch 14/20, Train Loss: 0.5066, Val Loss: 0.1172, Val Accuracy: 0.9604
Epoch 15/20, Train Loss: 0.4881, Val Loss: 0.1381, Val Accuracy: 0.9507
Epoch 16/20, Train Loss: 0.4825, Val Loss: 0.1335, Val Accuracy: 0.9536
Epoch 17/20, Train Loss: 0.4806, Val Loss: 0.0678, Val Accuracy: 0.9844
Epoch 18/20, Train Loss: 0.4847, Val Loss: 0.0728, Val Accuracy: 0.9756
Epoch 19/20, Train Loss: 0.4691, Val Loss: 0.0735, Val Accuracy: 0.9751
Epoch 20/20, Train Loss: 0.4712, Val Loss: 0.0687, Val Accuracy: 0.9790
```

Epoch 2 adımında anlık bir sapma meydana gelmekte.





LeViT Genel Model Sonuçları

5-Fold Cross-Validation Average Metrics:

Fold	3.000000
Accuracy	0.980664
Precision	0.980729
Recall (Sensitivity)	0.980664
Specificity	0.980596
F1-Score	0.980640
MCC	0.974243
AUC	0.987076

dtype: float64

5-Fold Cross-Validation Metrics

Fold	Accuracy	Precision	Recall (Sensitivity)	Specificity	F1-Score	MCC	AUC
1.0	0.9853515625	0.9855040921484852	0.9853515625	0.9854477552283063	0.9853639271384732	0.9805012203247712	0.9903113135636845
2.0	0.9750976562 5	0.9758836112435917	0.9750976562 5	0.9742612369786 34	0.9750472961567892	0.9667950827923253	0.9829974085868805
3.0	0.9809570312 5	0.9811367914276649	0.9809570312 5	0.9810169557057661	0.9809419475718107	0.9746078828898666	0.9873080019114834
4.0	0.9829101562 5	0.9829175554188018	0.9829101562 5	0.9829884802347855	0.9828864556627914	0.9577219908833283	0.9886389256911092
5.0	0.9790039062 5	0.9790019351622739	0.9790039062 5	0.9792669102859962	0.9789060174388959	0.9720276719893222	0.9861258520653679

Tabloların Detaylı ve Net Bir Şekilde İncelenmesi: DEViT

Fold 1

Metric	Value
Accuracy	0.9589331625
Precision	0.9853040521484852
Recall	0.9589331625
Specificity	0.9854477352288064
F1-Score	0.9583639713847372
MCC	0.986013022347712
AUC	0.9930113153636845

Fold 2

Metric	Value
Accuracy	0.9730570625
Precision	0.9730836112435917
Recall	0.9730570625
Specificity	0.974216239678634
F1-Score	0.9730742015617893
MCC	0.967905072932253
AUC	0.982974085808805

Fold 3

Metric	Value
Accuracy	0.9505703125
Precision	0.9811369741276649
Recall	0.9505703125
Specificity	0.981016095707661
F1-Score	0.95019457170107
MCC	0.974467882898666
AUC	0.98730011914834

Fold 4

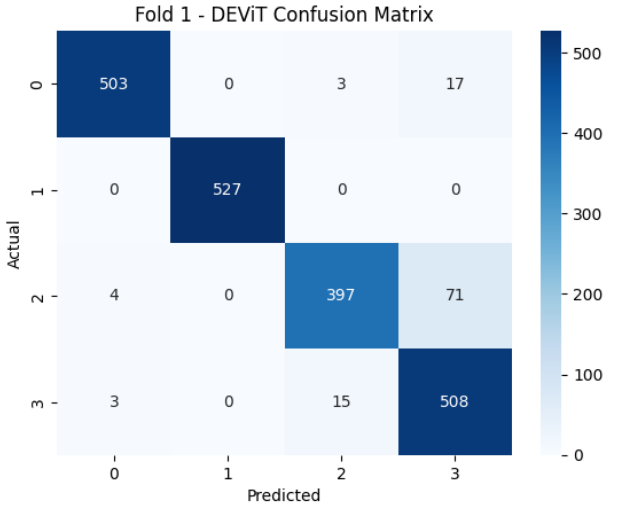
Metric	Value
Accuracy	0.9289110625
Precision	0.9289175531486018
Recall	0.9289110625
Specificity	0.928988840234785
F1-Score	0.928846546527914
MCC	0.971729888328363
AUC	0.985805265911092

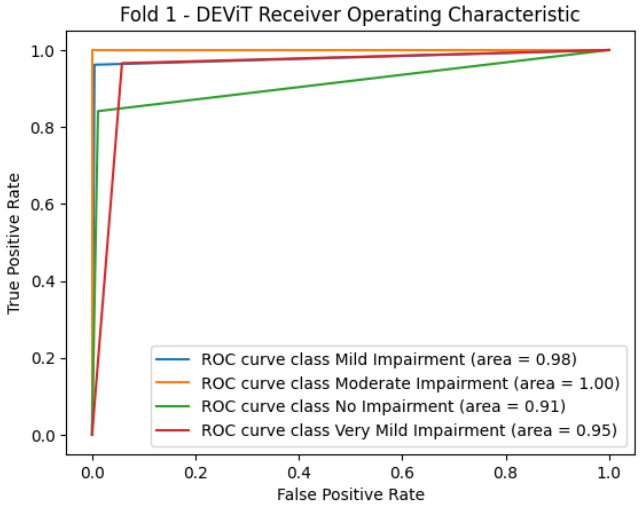
Fold 5

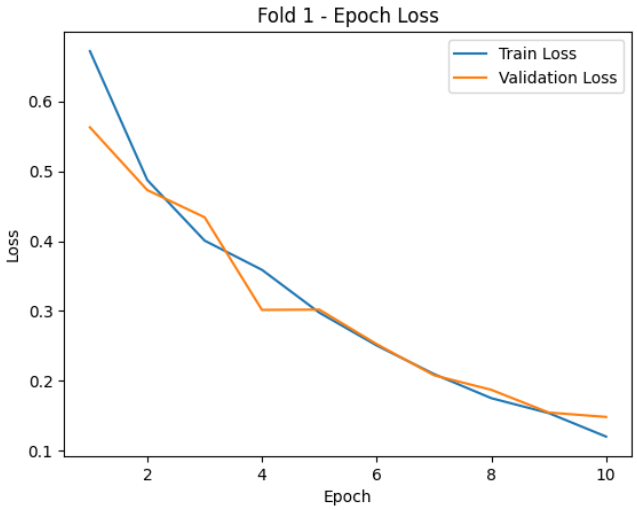
Metric	Value
Accuracy	0.97300390625
Precision	0.973001395122774
Recall	0.97300390625
Specificity	0.9732696102859062
F1-Score	0.9730061743389399
MCC	0.97202761189322
AUC	0.982611258203679

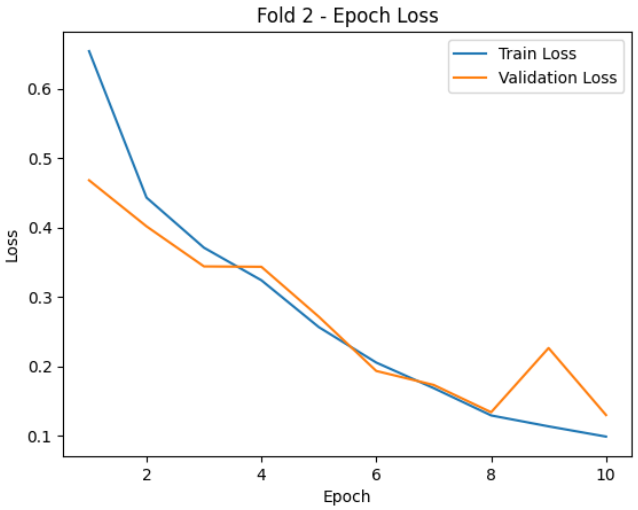
DEViT Fold 1

```
Epoch 1/10, Train Loss: 0.6717, Val Loss: 0.5627, Val Accuracy: 0.7407
Epoch 2/10, Train Loss: 0.4874, Val Loss: 0.4730, Val Accuracy: 0.7754
Epoch 3/10, Train Loss: 0.4007, Val Loss: 0.4341, Val Accuracy: 0.8159
Epoch 4/10, Train Loss: 0.3590, Val Loss: 0.3016, Val Accuracy: 0.8716
Epoch 5/10, Train Loss: 0.2977, Val Loss: 0.3021, Val Accuracy: 0.8657
Epoch 6/10, Train Loss: 0.2508, Val Loss: 0.2528, Val Accuracy: 0.8931
Epoch 7/10, Train Loss: 0.2099, Val Loss: 0.2082, Val Accuracy: 0.9150
Epoch 8/10, Train Loss: 0.1754, Val Loss: 0.1873, Val Accuracy: 0.9170
Epoch 9/10, Train Loss: 0.1541, Val Loss: 0.1549, Val Accuracy: 0.9360
Epoch 10/10, Train Loss: 0.1205, Val Loss: 0.1486, Val Accuracy: 0.9448
```







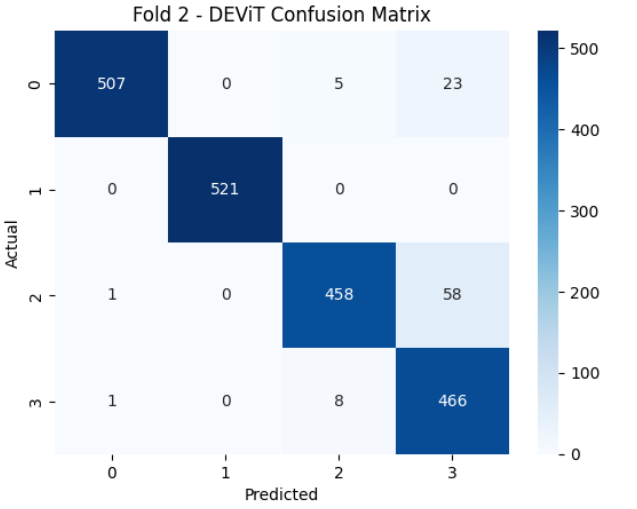


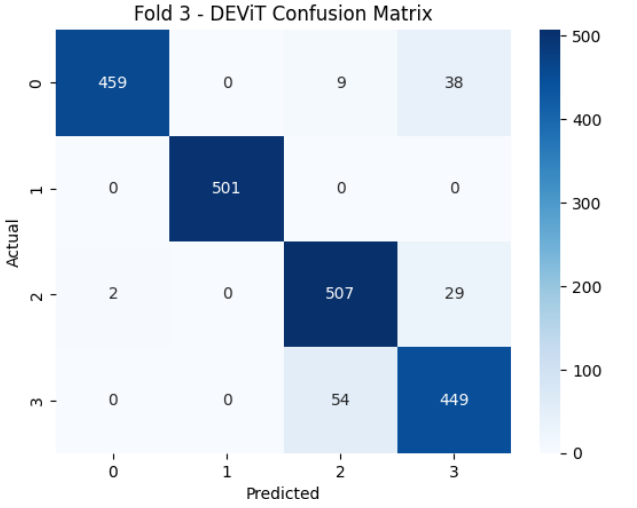
DEViT Fold 2

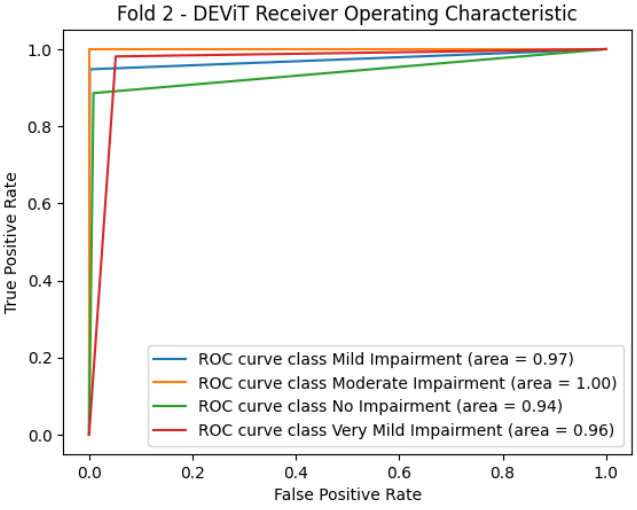
DEViT Fold 3

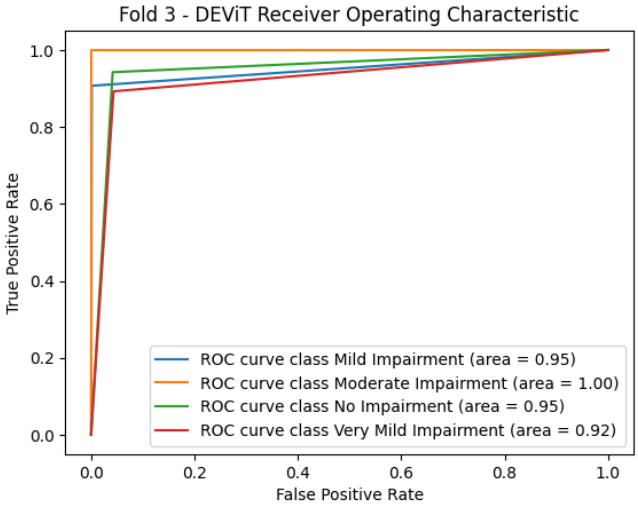
```
Epoch 1/10, Train Loss: 0.6540, Val Loss: 0.4680, Val Accuracy: 0.7935
Epoch 2/10, Train Loss: 0.4431, Val Loss: 0.4017, Val Accuracy: 0.8145
Epoch 3/10, Train Loss: 0.3709, Val Loss: 0.3439, Val Accuracy: 0.8340
Epoch 4/10, Train Loss: 0.3240, Val Loss: 0.3434, Val Accuracy: 0.8418
Epoch 5/10, Train Loss: 0.2565, Val Loss: 0.2715, Val Accuracy: 0.8789
Epoch 6/10, Train Loss: 0.2054, Val Loss: 0.1934, Val Accuracy: 0.9204
Epoch 7/10, Train Loss: 0.1686, Val Loss: 0.1732, Val Accuracy: 0.9312
Epoch 8/10, Train Loss: 0.1293, Val Loss: 0.1339, Val Accuracy: 0.9443
Epoch 9/10, Train Loss: 0.1136, Val Loss: 0.2264, Val Accuracy: 0.9199
Epoch 10/10, Train Loss: 0.0988, Val Loss: 0.1299, Val Accuracy: 0.9531
```

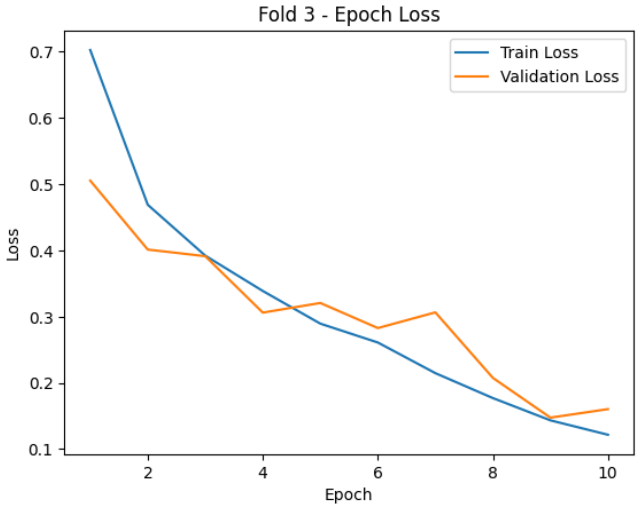
```
Epoch 1/10, Train Loss: 0.7025, Val Loss: 0.5054, Val Accuracy: 0.7656
Epoch 2/10, Train Loss: 0.4689, Val Loss: 0.4013, Val Accuracy: 0.8096
Epoch 3/10, Train Loss: 0.3921, Val Loss: 0.3913, Val Accuracy: 0.8345
Epoch 4/10, Train Loss: 0.3388, Val Loss: 0.3061, Val Accuracy: 0.8594
Epoch 5/10, Train Loss: 0.2895, Val Loss: 0.3207, Val Accuracy: 0.8687
Epoch 6/10, Train Loss: 0.2610, Val Loss: 0.2828, Val Accuracy: 0.8823
Epoch 7/10, Train Loss: 0.2147, Val Loss: 0.3065, Val Accuracy: 0.8789
Epoch 8/10, Train Loss: 0.1771, Val Loss: 0.2076, Val Accuracy: 0.9170
Epoch 9/10, Train Loss: 0.1435, Val Loss: 0.1476, Val Accuracy: 0.9414
Epoch 10/10, Train Loss: 0.1217, Val Loss: 0.1604, Val Accuracy: 0.9355
```

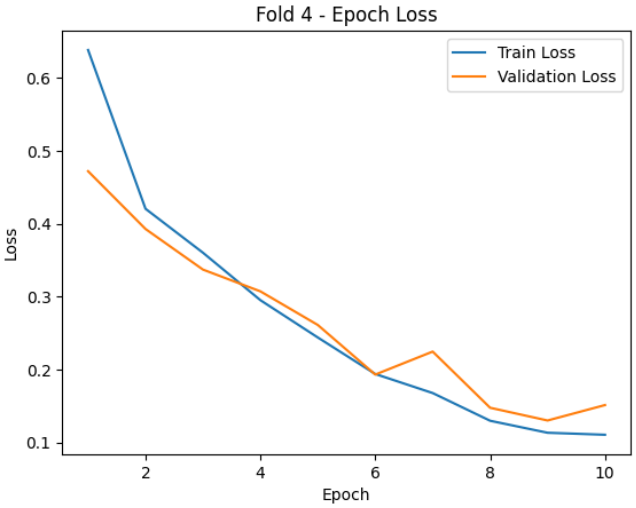










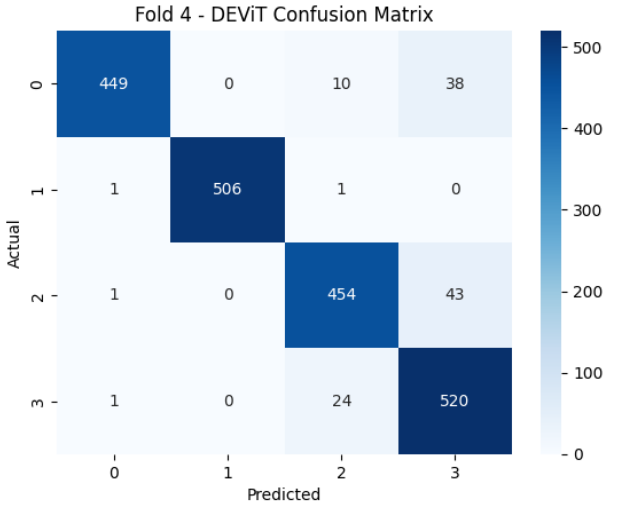


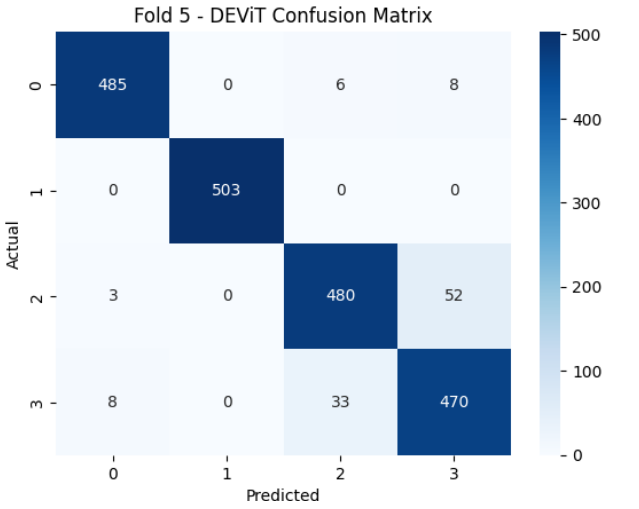
DEViT Fold 4

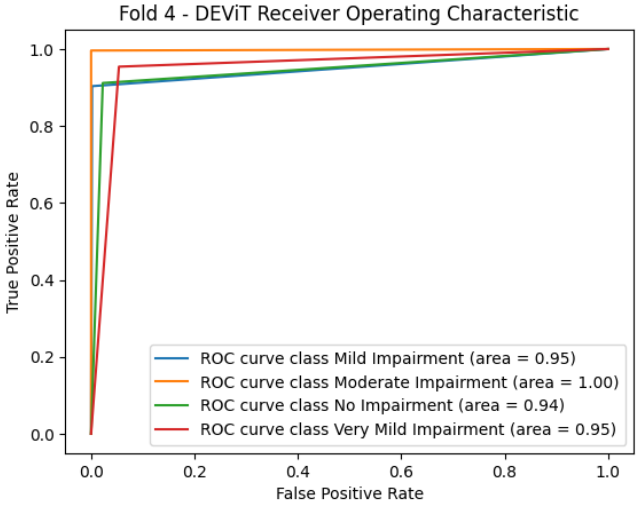
```
Epoch 1/10, Train Loss: 0.6381, Val Loss: 0.4718, Val Accuracy: 0.8027
Epoch 2/10, Train Loss: 0.4203, Val Loss: 0.3926, Val Accuracy: 0.8262
Epoch 3/10, Train Loss: 0.3601, Val Loss: 0.3369, Val Accuracy: 0.8657
Epoch 4/10, Train Loss: 0.2950, Val Loss: 0.3071, Val Accuracy: 0.8765
Epoch 5/10, Train Loss: 0.2438, Val Loss: 0.2609, Val Accuracy: 0.8945
Epoch 6/10, Train Loss: 0.1937, Val Loss: 0.1929, Val Accuracy: 0.9258
Epoch 7/10, Train Loss: 0.1676, Val Loss: 0.2245, Val Accuracy: 0.9111
Epoch 8/10, Train Loss: 0.1296, Val Loss: 0.1474, Val Accuracy: 0.9438
Epoch 9/10, Train Loss: 0.1131, Val Loss: 0.1299, Val Accuracy: 0.9478
Epoch 10/10, Train Loss: 0.1104, Val Loss: 0.1511, Val Accuracy: 0.9419
```

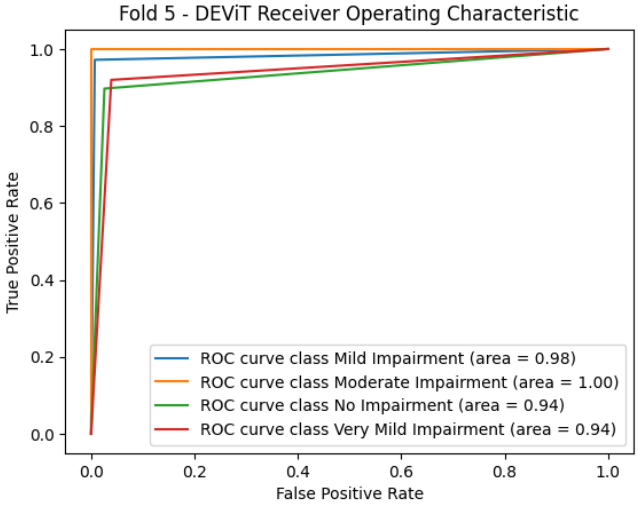
DEViT Fold 5

```
Epoch 1/10, Train Loss: 0.6573, Val Loss: 0.5074, Val Accuracy: 0.7549
Epoch 2/10, Train Loss: 0.4401, Val Loss: 0.4136, Val Accuracy: 0.7959
Epoch 3/10, Train Loss: 0.3697, Val Loss: 0.3388, Val Accuracy: 0.8530
Epoch 4/10, Train Loss: 0.3093, Val Loss: 0.3031, Val Accuracy: 0.8755
Epoch 5/10, Train Loss: 0.2604, Val Loss: 0.2549, Val Accuracy: 0.8936
Epoch 6/10, Train Loss: 0.2115, Val Loss: 0.2313, Val Accuracy: 0.9023
Epoch 7/10, Train Loss: 0.1784, Val Loss: 0.2850, Val Accuracy: 0.8979
Epoch 8/10, Train Loss: 0.1416, Val Loss: 0.1890, Val Accuracy: 0.9282
Epoch 9/10, Train Loss: 0.1266, Val Loss: 0.1928, Val Accuracy: 0.9238
Epoch 10/10, Train Loss: 0.1088, Val Loss: 0.1399, Val Accuracy: 0.9463
```









DEViT Genel Model Sonuçları

5-Fold Cross-Validation Average Metrics:

Fold	3.000000
Accuracy	0.944336
Precision	0.947216
Recall (Sensitivity)	0.944336
Specificity	0.943977
F1-Score	0.944673
MCC	0.926480
AUC	0.962692

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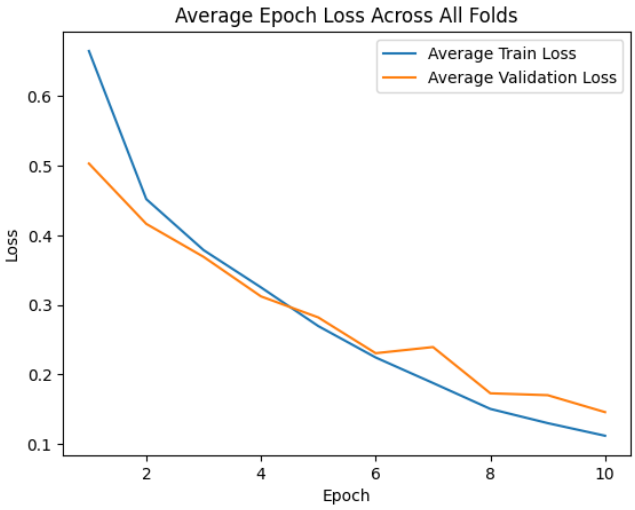


5-Fold Cross-Validation Metrics

Fold	Accuracy	Precision	Recall (Sensitivity)	Specificity	F1-Score	MCC	AUC
1.0	0.9448421875	0.9485765688507	0.9448421875	0.9421606012034 59	0.9448967478058 59	0.9275399524724215	0.9618512626780138
2.0	0.953125	0.9576011268252341	0.953125	0.9536490650875 64	0.9536721571408284	0.9387190610213785	0.9691611550582648
3.0	0.935546875	0.9380027338064748	0.935546875	0.9355344854627323	0.9360298397282523	0.9144789286381232	0.9569691718615242
4.0	0.9418945313 5	0.9451194221775125	0.9418945313 5	0.9413146354942928	0.9423918728192182	0.9231950612426403	0.9608564306587787
5.0	0.9462890625	0.9467119749020672	0.9462890625	0.9472263289495757	0.9463723383624769	0.9284679758780328	0.9646237840097336

Tabloların Detaylı ve Net Bir Şekilde İncelenmesi:

Fold 1

Metric	Value
Accuracy	0.9448421875
Precision	0.94857306880307
Recall	0.9448421875
Specificity	0.942160601203459
F1-Score	0.944896747805859
MCC	0.875739534724215
AUC	0.961851226708138

Fold 2

Metric	Value
Accuracy	0.935125
Precision	0.9576011268252341
Recall	0.935125
Specificity	0.953469058073064
F1-Score	0.935701714100284
MCC	0.938719010231785
AUC	0.969151105798268

Fold 3

Metric	Value
Accuracy	0.935546875
Precision	0.938002733064748
Recall	0.935546875
Specificity	0.935534456147233
F1-Score	0.936028972052253
MCC	0.914478928013252
AUC	0.956097180612542

Fold 4

Metric	Value
Accuracy	0.9458984375
Precision	0.943911249577125
Recall	0.9458984375
Specificity	0.941236405494228
F1-Score	0.9439123873912812
MCC	0.923159001246043
AUC	0.950683045078787

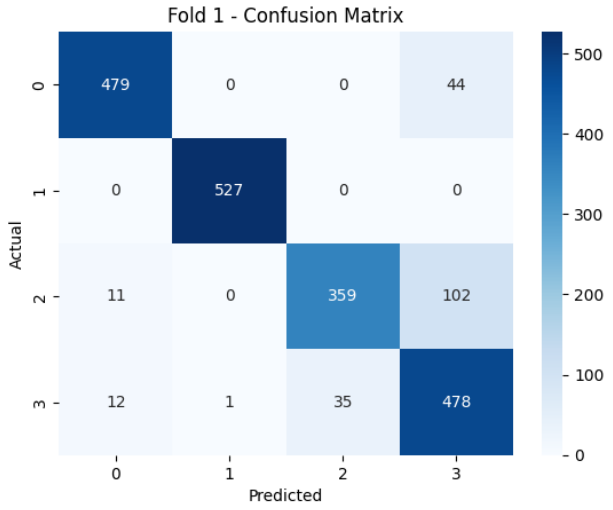
Fold 5

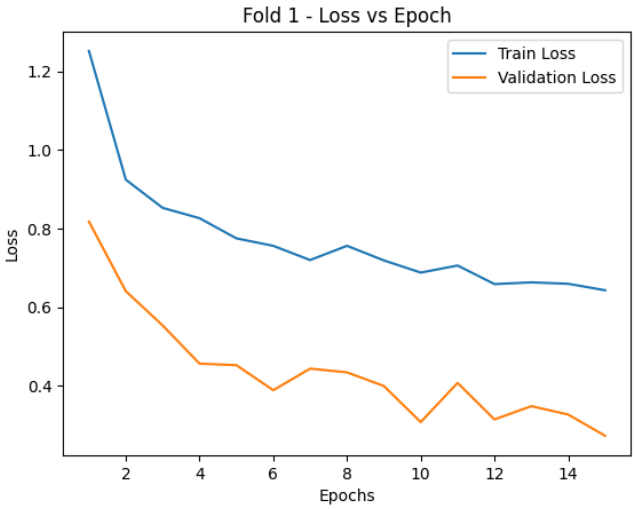
Metric	Value
Accuracy	0.9462890625
Precision	0.9467119743020672
Recall	0.9462890625
Specificity	0.9472202389457377
F1-Score	0.9463721833024769
MCC	0.928467597882028
AUC	0.9464327480097336

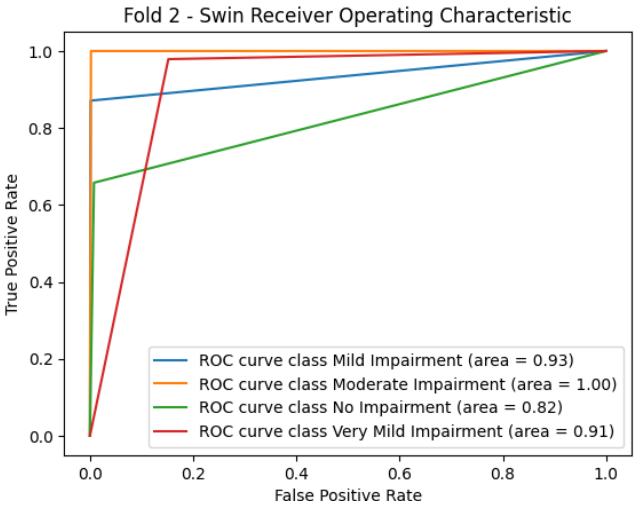
Swin

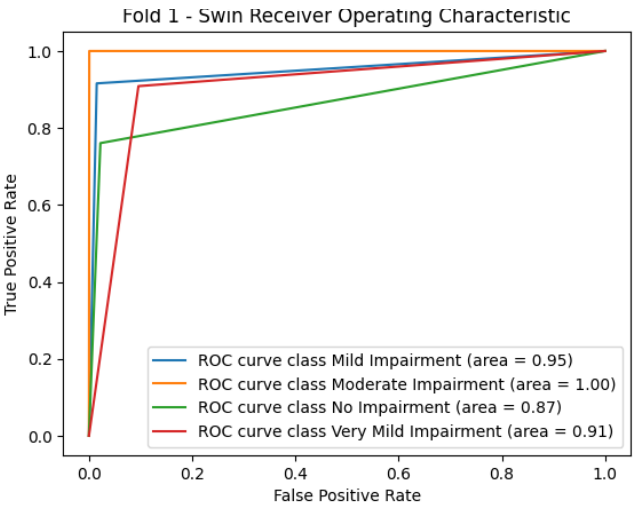
Swin Fold 1

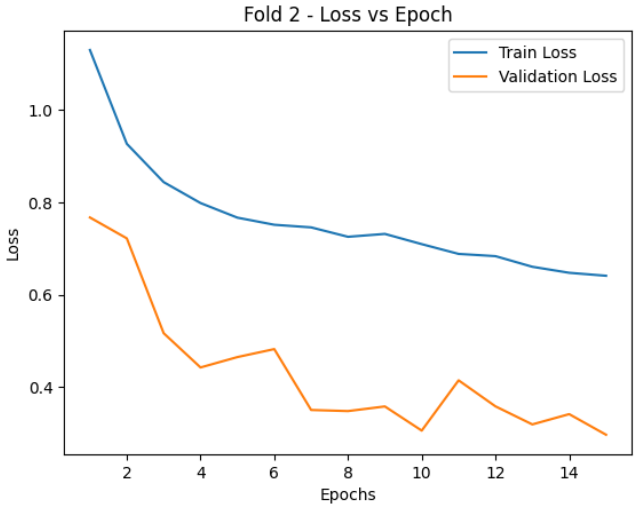
```
Epoch 1/15, Train Loss: 1.2520, Val Loss: 0.8180, Val Accuracy: 0.6060
Epoch 2/15, Train Loss: 0.9246, Val Loss: 0.6409, Val Accuracy: 0.7324
Epoch 3/15, Train Loss: 0.8528, Val Loss: 0.5536, Val Accuracy: 0.7153
Epoch 4/15, Train Loss: 0.8265, Val Loss: 0.4564, Val Accuracy: 0.8057
Epoch 5/15, Train Loss: 0.7752, Val Loss: 0.4526, Val Accuracy: 0.7866
Epoch 6/15, Train Loss: 0.7562, Val Loss: 0.3888, Val Accuracy: 0.8276
Epoch 7/15, Train Loss: 0.7201, Val Loss: 0.4437, Val Accuracy: 0.8193
Epoch 8/15, Train Loss: 0.7563, Val Loss: 0.4342, Val Accuracy: 0.8086
Epoch 9/15, Train Loss: 0.7191, Val Loss: 0.3996, Val Accuracy: 0.8354
Epoch 10/15, Train Loss: 0.6881, Val Loss: 0.3077, Val Accuracy: 0.8765
Epoch 11/15, Train Loss: 0.7062, Val Loss: 0.4075, Val Accuracy: 0.8276
Epoch 12/15, Train Loss: 0.6589, Val Loss: 0.3144, Val Accuracy: 0.8862
Epoch 13/15, Train Loss: 0.6632, Val Loss: 0.3482, Val Accuracy: 0.8389
Epoch 14/15, Train Loss: 0.6596, Val Loss: 0.3268, Val Accuracy: 0.8584
Epoch 15/15, Train Loss: 0.6432, Val Loss: 0.2729, Val Accuracy: 0.8999
```









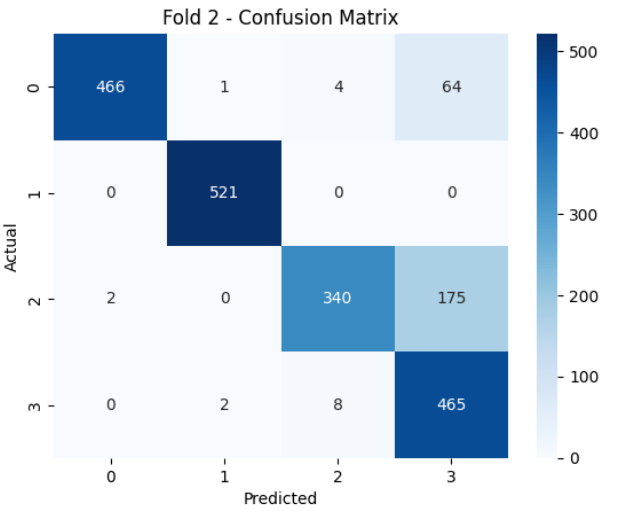


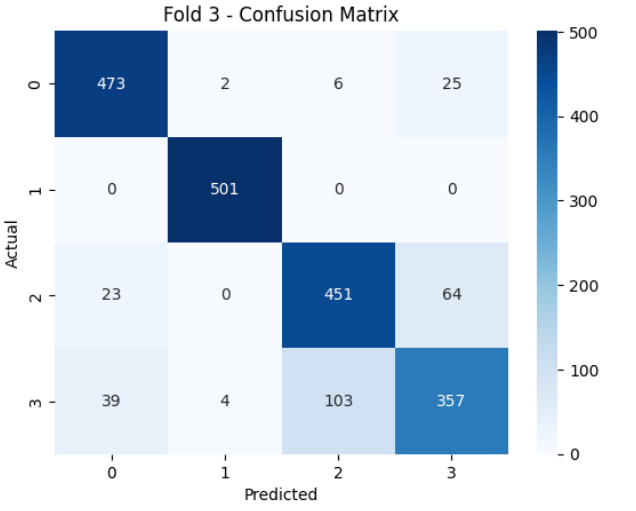
Swin Fold 2

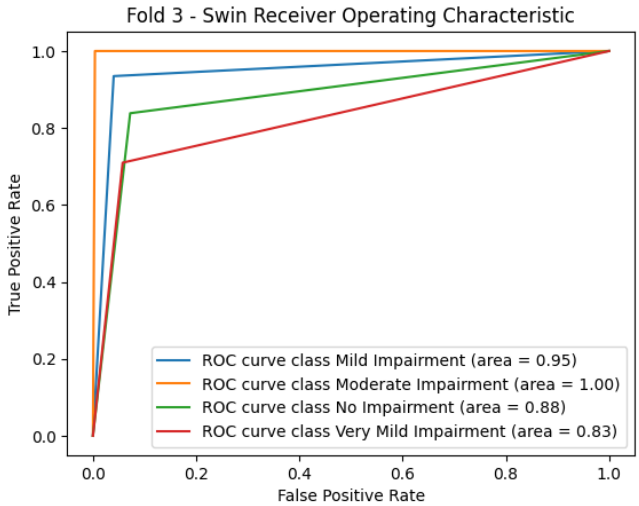
```
Epoch 1/15, Train Loss: 1.1303, Val Loss: 0.7676, Val Accuracy: 0.5894
Epoch 2/15, Train Loss: 0.9272, Val Loss: 0.7223, Val Accuracy: 0.7480
Epoch 3/15, Train Loss: 0.8442, Val Loss: 0.5170, Val Accuracy: 0.7588
Epoch 4/15, Train Loss: 0.7988, Val Loss: 0.4427, Val Accuracy: 0.7983
Epoch 5/15, Train Loss: 0.7672, Val Loss: 0.4652, Val Accuracy: 0.8188
Epoch 6/15, Train Loss: 0.7518, Val Loss: 0.4825, Val Accuracy: 0.7969
Epoch 7/15, Train Loss: 0.7461, Val Loss: 0.3507, Val Accuracy: 0.8599
Epoch 8/15, Train Loss: 0.7257, Val Loss: 0.3482, Val Accuracy: 0.8687
Epoch 9/15, Train Loss: 0.7320, Val Loss: 0.3583, Val Accuracy: 0.8564
Epoch 10/15, Train Loss: 0.7098, Val Loss: 0.3060, Val Accuracy: 0.8760
Epoch 11/15, Train Loss: 0.6887, Val Loss: 0.4149, Val Accuracy: 0.8188
Epoch 12/15, Train Loss: 0.6838, Val Loss: 0.3585, Val Accuracy: 0.8525
Epoch 13/15, Train Loss: 0.6608, Val Loss: 0.3194, Val Accuracy: 0.8618
Epoch 14/15, Train Loss: 0.6478, Val Loss: 0.3417, Val Accuracy: 0.8569
Epoch 15/15, Train Loss: 0.6413, Val Loss: 0.2970, Val Accuracy: 0.8750
```

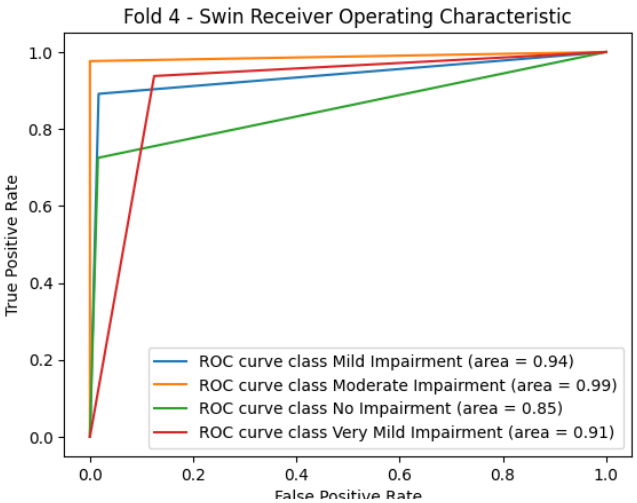
Swin Fold 3

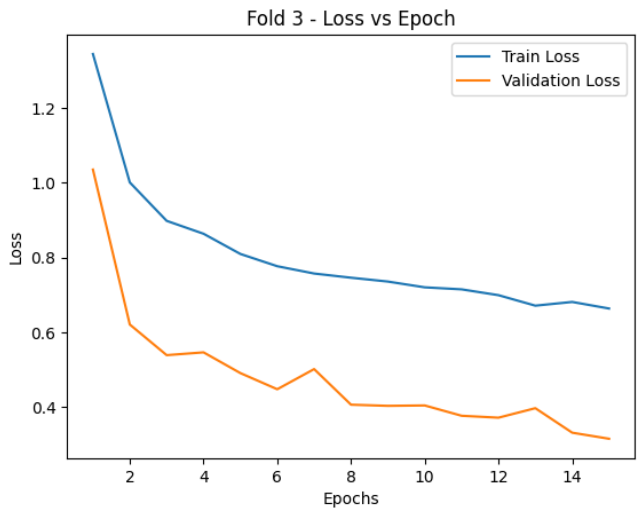
```
Epoch 1/15, Train Loss: 1.3436, Val Loss: 1.0347, Val Accuracy: 0.5356
Epoch 2/15, Train Loss: 1.0004, Val Loss: 0.6207, Val Accuracy: 0.7183
Epoch 3/15, Train Loss: 0.8977, Val Loss: 0.5388, Val Accuracy: 0.7646
Epoch 4/15, Train Loss: 0.8632, Val Loss: 0.5463, Val Accuracy: 0.7681
Epoch 5/15, Train Loss: 0.8092, Val Loss: 0.4908, Val Accuracy: 0.7759
Epoch 6/15, Train Loss: 0.7765, Val Loss: 0.4477, Val Accuracy: 0.7944
Epoch 7/15, Train Loss: 0.7570, Val Loss: 0.5016, Val Accuracy: 0.7778
Epoch 8/15, Train Loss: 0.7458, Val Loss: 0.4064, Val Accuracy: 0.8262
Epoch 9/15, Train Loss: 0.7355, Val Loss: 0.4033, Val Accuracy: 0.8174
Epoch 10/15, Train Loss: 0.7200, Val Loss: 0.4044, Val Accuracy: 0.8398
Epoch 11/15, Train Loss: 0.7147, Val Loss: 0.3768, Val Accuracy: 0.8301
Epoch 12/15, Train Loss: 0.6991, Val Loss: 0.3717, Val Accuracy: 0.8413
Epoch 13/15, Train Loss: 0.6711, Val Loss: 0.3971, Val Accuracy: 0.8281
Epoch 14/15, Train Loss: 0.6810, Val Loss: 0.3316, Val Accuracy: 0.8472
Epoch 15/15, Train Loss: 0.6634, Val Loss: 0.3154, Val Accuracy: 0.8701
```

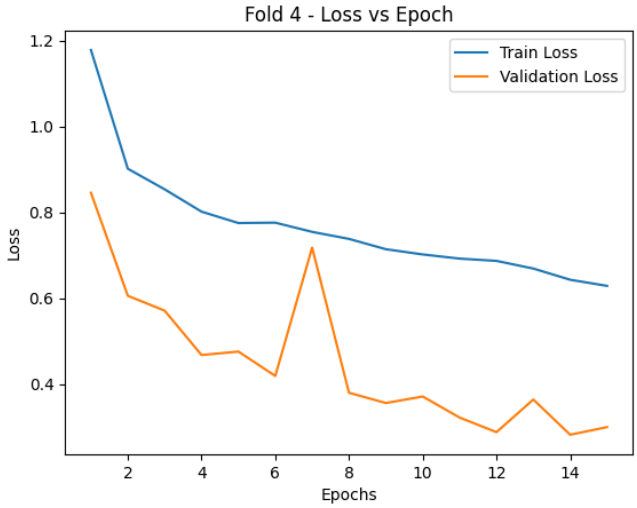










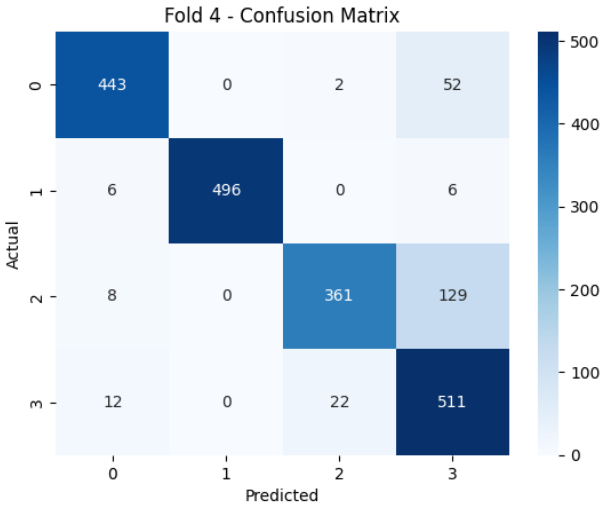


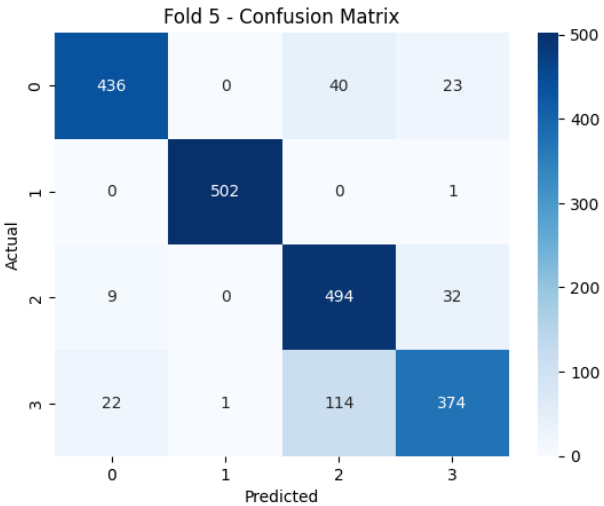
Swin Fold 4

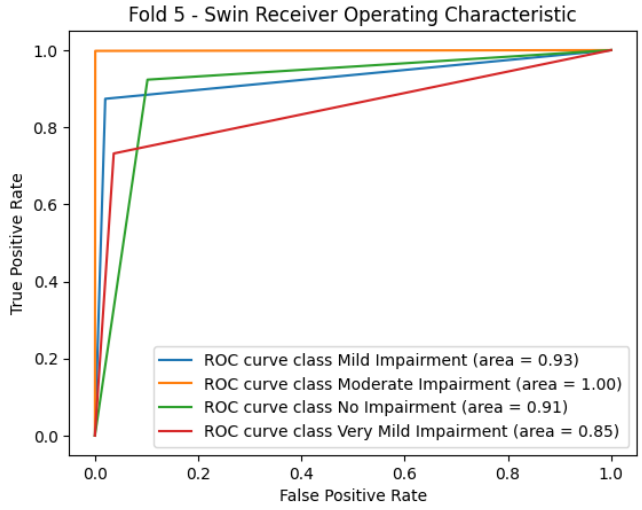
Swin Fold 5

```
Epoch 1/15, Train Loss: 1.1776, Val Loss: 0.8452, Val Accuracy: 0.5430
Epoch 2/15, Train Loss: 0.9012, Val Loss: 0.6054, Val Accuracy: 0.7456
Epoch 3/15, Train Loss: 0.8532, Val Loss: 0.5707, Val Accuracy: 0.7539
Epoch 4/15, Train Loss: 0.8012, Val Loss: 0.4674, Val Accuracy: 0.7856
Epoch 5/15, Train Loss: 0.7747, Val Loss: 0.4755, Val Accuracy: 0.8193
Epoch 6/15, Train Loss: 0.7756, Val Loss: 0.4187, Val Accuracy: 0.8242
Epoch 7/15, Train Loss: 0.7542, Val Loss: 0.7175, Val Accuracy: 0.7402
Epoch 8/15, Train Loss: 0.7378, Val Loss: 0.3795, Val Accuracy: 0.8408
Epoch 9/15, Train Loss: 0.7138, Val Loss: 0.3556, Val Accuracy: 0.8555
Epoch 10/15, Train Loss: 0.7016, Val Loss: 0.3708, Val Accuracy: 0.8525
Epoch 11/15, Train Loss: 0.6919, Val Loss: 0.3218, Val Accuracy: 0.8735
Epoch 12/15, Train Loss: 0.6866, Val Loss: 0.2878, Val Accuracy: 0.8882
Epoch 13/15, Train Loss: 0.6688, Val Loss: 0.3638, Val Accuracy: 0.8579
Epoch 14/15, Train Loss: 0.6427, Val Loss: 0.2818, Val Accuracy: 0.8804
Epoch 15/15, Train Loss: 0.6284, Val Loss: 0.2996, Val Accuracy: 0.8843
```

```
Epoch 1/15, Train Loss: 1.1828, Val Loss: 0.7500, Val Accuracy: 0.6753
Epoch 2/15, Train Loss: 0.9130, Val Loss: 0.5690, Val Accuracy: 0.7666
Epoch 3/15, Train Loss: 0.8704, Val Loss: 0.6005, Val Accuracy: 0.7402
Epoch 4/15, Train Loss: 0.8014, Val Loss: 0.4335, Val Accuracy: 0.8140
Epoch 5/15, Train Loss: 0.7678, Val Loss: 0.4569, Val Accuracy: 0.7881
Epoch 6/15, Train Loss: 0.7494, Val Loss: 0.3697, Val Accuracy: 0.8452
Epoch 7/15, Train Loss: 0.7219, Val Loss: 0.4321, Val Accuracy: 0.8413
Epoch 8/15, Train Loss: 0.7081, Val Loss: 0.3853, Val Accuracy: 0.8340
Epoch 9/15, Train Loss: 0.6879, Val Loss: 0.3306, Val Accuracy: 0.8740
Epoch 10/15, Train Loss: 0.6846, Val Loss: 0.3176, Val Accuracy: 0.8901
Epoch 11/15, Train Loss: 0.6588, Val Loss: 0.4657, Val Accuracy: 0.8125
Epoch 12/15, Train Loss: 0.6606, Val Loss: 0.3538, Val Accuracy: 0.8613
Epoch 13/15, Train Loss: 0.6212, Val Loss: 0.3159, Val Accuracy: 0.8735
Epoch 14/15, Train Loss: 0.6146, Val Loss: 0.2891, Val Accuracy: 0.8818
Epoch 15/15, Train Loss: 0.6254, Val Loss: 0.2999, Val Accuracy: 0.8818
```







Swin Genel Model Sonuçları

5-Fold Cross-Validation Average Metrics:

Fold	3.000000
Accuracy	0.882227
Precision	0.894903
Recall (Sensitivity)	0.882227
Specificity	0.881645
F1-Score	0.882476
MCC	0.847257
AUC	0.921164

dtype: float64

5-Fold Cross-Validation Metrics

Fold	Accuracy	Precision	Recall (Sensitivity)	Specificity	F1-Score	MCC	AUC
1.0	0.89990234375	0.9072402381417512	0.89990234375	0.8963021120917033	0.9003491662138531	0.8685015454100756	0.9331416810564228
2.0	0.875	0.9108823967350913	0.875	0.8763903909478136	0.8768905352759663	0.8451147405115826	0.9180690174767991
3.0	0.8701171875	0.8683298129765482	0.8701171875	0.8707035305541895	0.8682647877323565	0.8273330611996029	0.9136171895743934
4.0	0.88427734375	0.9000945198713763	0.88427734375	0.8825600790449374	0.8852873153536965	0.8503304427440018	0.9321993047677308
5.0	0.8818359375	0.8887606853418756	0.8818359375	0.8811755370370664	0.8815672179003874	0.8448992095250513	0.9210178550061141

Tabloların Detaylı ve Net Bir Şekilde İncelenmesi:

FOLD 1

Metric	Value
Accuracy	0.89390234375
Precision	0.897042368147512
Recall (Sensitivity)	0.89390234375
Specificity	0.8936021120917033
F1-Score	0.903043612138531
MCC	0.858104541030756
AUC	0.9341486105644228

FOLD 2

Metric	Value
Accuracy	0.875
Precision	0.910823623570913
Recall (Sensitivity)	0.875
Specificity	0.8763095934781038
F1-Score	0.8760953253759604
MCC	0.845114741051826
AUC	0.919080174676991

FOLD 3

Metric	Value
Accuracy	0.870171875
Precision	0.888329125793482
Recall (Sensitivity)	0.870171875
Specificity	0.870703350354189
F1-Score	0.88248787232365
MCC	0.827334031939029
AUC	0.913167879473394

FOLD 4

Metric	Value
Accuracy	0.88427734375
Precision	0.9000549918713763
Recall (Sensitivity)	0.88427734375
Specificity	0.8852500754494373
F1-Score	0.8852837513535095
MCC	0.8303542647440018
AUC	0.921069597407706

FOLD 5

Metric	Value
Accuracy	0.8818359375
Precision	0.888706093418756
Recall (Sensitivity)	0.8818359375
Specificity	0.8811735370370664
F1-Score	0.881521773003874
MCC	0.8448992097520313

IV. TRANSFORMATÖR MODELLERİ HAKKINDA BİLGİLER

1) 1. Google ViT (Vision Transformer)

- Geliştirici: Google Research
- Yayınlanma Tarihi: Ekim 2020
- Detaylar:
  - ViT, görüntüleri, doğal dil işleme (NLP) görevlerinde yaygın olarak kullanılan transformatörler gibi işlemeyi amaçlayan ilk büyük modeldir.
  - Görüntüleri, belirli boyutlarda küçük parçalara (patch) böler ve bu parçaları bir dizi olarak işler.
  - Büyük ölçekli veri kümeleri üzerinde önceden eğitildiğinde, ViT modelleri, CNN tabanlı modellerden daha iyi performans gösterebilir.
  - Makale: "An Image is Worth 16x16 Words: Transformers for Image Recognition at Scale"

2) 2. Microsoft BeiT (BERT Pre-Training of Image Transformers)

- Geliştirici: Microsoft Research
- Yayınlanma Tarihi: Mart 2021
- Detaylar:
    - BeiT, BERT'in metinler için yaptığı gibi, görüntüler için önceden eğitim kullanır.
    - Görüntü parçalarını maskeleyip yeniden yapılandırarak transformatörleri eğitir.
    - Bu yöntem, önceden eğitimli modellerin genel performansını artırır.
    - Makale: "BEiT: BERT Pre-Training of Image Transformers"

3) 3. DeiT (Data-efficient Image Transformers)

- Geliştirici: Facebook AI Research (FAIR)
- Yayınlanma Tarihi: Aralık 2020
- Detaylar:
    - DeiT, daha az veri kullanarak transformatör modellerini verimli bir şekilde eğitmeyi amaçlar.
    - Veri verimliliği, veri artırım teknikleri ve bilgi aktarımı yöntemleri ile sağlanır.
    - Bu model, çok büyük veri setlerine ihtiyaç duymadan yüksek performans sağlar.
    - Makale: "Training data-efficient image transformers & distillation through attention"

4) 4. LeViT

- Geliştirici: Facebook AI Research (FAIR)
- Yayınlanma Tarihi: Temmuz 2021
- Detaylar:
    - LeViT, düşük gecikme ve yüksek verimlilik ile çalışmak üzere optimize edilmiştir.
    - Hibrit bir modeldir; transformatör ve konvolüsyonel katmanları birleştirir.
    - Özellikle mobil cihazlarda ve gerçek zamanlı uygulamalarda kullanılmak üzere tasarlanmıştır.
    - Makale: "LeViT: a Vision Transformer in ConvNet's Clothing for Faster Inference"

5) 5. Swin Transformer

- Geliştirici: Microsoft Research Asia
- Yayınlanma Tarihi: Mart 2021
- Detaylar:
    - Swin Transformer, ölçeklenebilir bir yapıya sahiptir ve farklı çözünürlüklerdeki görüntülerde iyi performans gösterir.
    - Yerel ve küresel özellikleri verimli bir şekilde yakalayarak, nesne algılama ve segmentasyon gibi görevlerde üstün performans sağlar.
    - Esnek ve hiyerarşik bir yapı kullanarak görüntü boyutuna göre kendini uyarlayabilir.
    - Makale: "Swin Transformer: Hierarchical Vision Transformer using Shifted Windows"

V. Sonuç

Bu çalışma, Dönüştürücü (Transformer) modellerinin tıbbi görüntü sınıflandırma görevlerinde, özellikle Alzheimer hastalığının tespitinde etkinliğini göstermektedir. Gelecekteki çalışmalar, daha derin model mimarilerini ve alternatif veri artırma tekniklerini araştırarak performansı daha da artırabilir.

VI. İlgili Derleme Kodları


Google ViT.txt


Microsoft BeiT.txt


DEViT.txt


Swin.txt


LeViT.txt

Google Colab Linki:
https://colab.research.google.com/drive/1oKb48oyTCJRf15cnUR0sxCnh2iSYeiCX?usp=sharing

VII. KAYNAKÇA

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[5] Liu, Z., Lin, Y., Cao, Y., Hu, H., Wei, Y., Zhang, Z., ... & Guo, B. (2021). Swin Transformer: Hierarchical Vision Transformer using Shifted Windows. arXiv preprint arXiv:2103.14030.

[6] He, K., Zhang, X., Ren, S., & Sun, J. (2016). Deep Residual Learning for Image Recognition. Proceedings of the IEEE conference on computer vision and pattern recognition, 770-778.

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