Hackathon Test Data Results

Problem Statement(s)

1. Segment the respiratory cycles from the audio files respectively and annotate accordingly
2. Then build two models:
    a. a model to classify respiratory diseases, i.e., COPD, LRTI, URTI
    b. a model to detect if a recording contains crackles, wheezes, both or none.

Solutions

1. Segmentation of Respiratory Cycles from the audio files.

Segments of Respiratory Cycles were extracted from the WAV files and each segment was appropriately annotated as shown in the following figure (Figure 1).

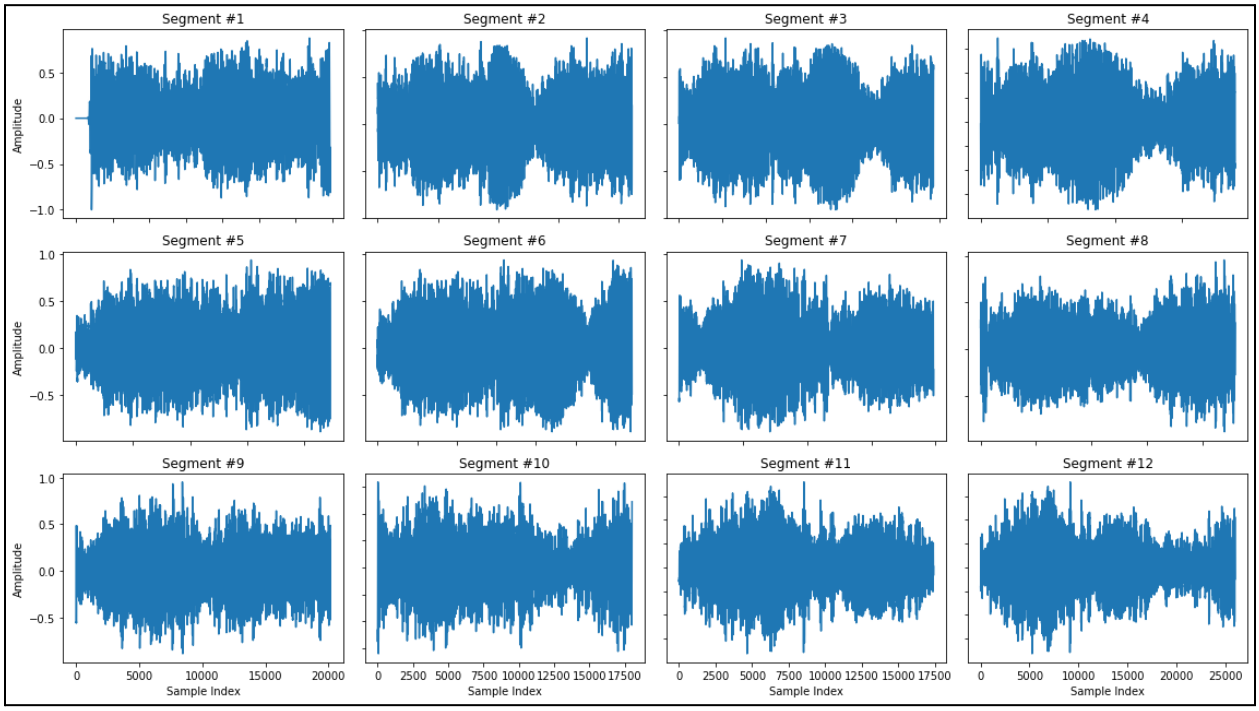


Figure 1. Sample Segments of Respiratory Cycles

Code for the same, and the related results are presented in the following Google Colab Notebook - https://colab.research.google.com/drive/13EXSjYrrm0M2nSWGJVr13bxcVW75KADM?usp=sharing

2(a). Performance of Model to Classify Respiratory Diseases

2(a).1 Input Test Data Files versus Model Prediction (Table 1).

S.No.	File Name	Predicted Class
1	112_1b1_Ar_sc_Meditron.wav	0
2	112_1b1_Lr_sc_Meditron.wav	0
3	112_1p1_Ll_sc_Litt3200.wav	0
4	112_1p1_Pl_sc_Litt3200.wav	0
5	112_1p1_Pr_sc_Litt3200.wav	0
6	115_1b1_Ar_sc_Meditron.wav	0
7	116_1b2_Pl_sc_Meditron.wav	0
8	116_1b2_Tc_sc_Meditron.wav	0
9	117_1b2_Tc_mc_LittC2SE.wav	0
10	117_1b3_Tc_mc_LittC2SE.wav	0
11	118_1b1_Al_sc_Litt3200.wav	0
12	118_1b1_Ar_sc_Litt3200.wav	0
13	118_1b1_Ll_sc_Litt3200.wav	0
14	118_1b1_Lr_sc_Litt3200.wav	0
15	118_1b1_Pl_sc_Litt3200.wav	0
16	118_1b1_Pr_sc_Litt3200.wav	0
17	119_1b1_Ar_sc_Meditron.wav	1
18	120_1b1_Al_sc_Meditron.wav	0
19	120_1b1_Ar_sc_Meditron.wav	0
20	120_1b1_Lr_sc_Meditron.wav	0
21	120_1b1_Pl_sc_Meditron.wav	0
22	120_1b1_Pr_sc_Meditron.wav	0
23	131_1b1_Al_sc_Meditron.wav	1
24	132_2b1_Lr_mc_LittC2SE.wav	0
25	132_2b2_Lr_mc_LittC2SE.wav	0
26	146_2b2_Pl_mc_AKGC417L.wav	0
27	146_2b4_Al_mc_AKGC417L.wav	0
28	146_2b4_Ar_mc_AKGC417L.wav	0
29	146_2b4_Ll_mc_AKGC417L.wav	0
30	146_2b4_Lr_mc_AKGC417L.wav	0

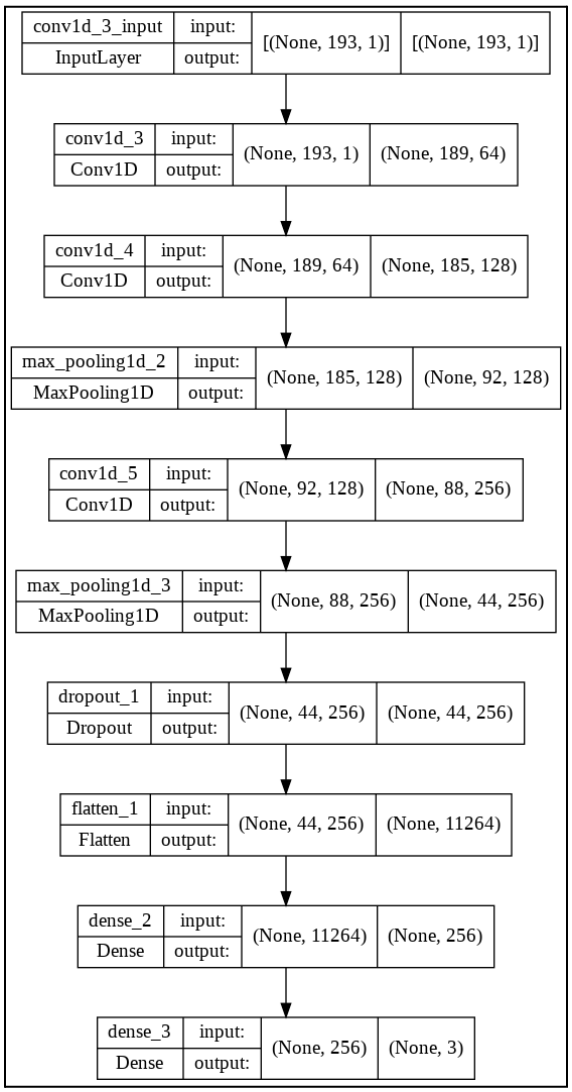
31	146_2b4_Pr_mc_AKGC417L.wav	0
32	146_8p3_Al_mc_AKGC417L.wav	0
33	146_8p3_Ar_mc_AKGC417L.wav	0
34	146_8p3_Lr_mc_AKGC417L.wav	0
35	146_8p3_Pl_mc_AKGC417L.wav	0
36	146_8p3_Pr_mc_AKGC417L.wav	0
37	160_1b2_Al_mc_AKGC417L.wav	0
38	160_1b2_Ar_mc_AKGC417L.wav	0
39	160_1b2_Lr_mc_AKGC417L.wav	0
40	160_1b2_Pl_mc_AKGC417L.wav	0
41	160_1b2_Pr_mc_AKGC417L.wav	0
42	160_1b2_Tc_mc_AKGC417L.wav	0
43	160_1b3_Al_mc_AKGC417L.wav	0
44	160_1b3_Ar_mc_AKGC417L.wav	0
45	160_1b3_Lr_mc_AKGC417L.wav	0
46	160_1b3_Pl_mc_AKGC417L.wav	0
47	160_1b3_Pr_mc_AKGC417L.wav	0
48	160_1b3_Tc_mc_AKGC417L.wav	0
49	160_1b4_Al_mc_AKGC417L.wav	0
50	160_1b4_Ar_mc_AKGC417L.wav	0
51	160_1b4_Lr_mc_AKGC417L.wav	0
52	160_1b4_Pl_mc_AKGC417L.wav	0
53	160_1b4_Pr_mc_AKGC417L.wav	0
54	160_1b4_Tc_mc_AKGC417L.wav	0
55	160_2b3_Lr_mc_AKGC417L.wav	0
56	160_2b4_Ar_mc_AKGC417L.wav	0
57	160_2b4_Pl_mc_AKGC417L.wav	0
58	160_2b4_Pr_mc_AKGC417L.wav	0
59	160_2b4_Tc_mc_AKGC417L.wav	0
60	203_1p2_Al_mc_AKGC417L.wav	0
61	203_1p2_Ar_mc_AKGC417L.wav	0
62	203_1p2_Lr_mc_AKGC417L.wav	0
63	203_1p2_Pl_mc_AKGC417L.wav	0
64	203_1p2_Pr_mc_AKGC417L.wav	0
65	203_1p2_Tc_mc_AKGC417L.wav	0

66	203_1p3_Al_mc_AKGC417L.wav	0
67	203_1p3_Ar_mc_AKGC417L.wav	0
68	203_1p3_Pl_mc_AKGC417L.wav	0
69	203_1p3_Pr_mc_AKGC417L.wav	0
70	203_1p3_Tc_mc_AKGC417L.wav	0
71	203_1p4_Al_mc_AKGC417L.wav	0
72	203_1p4_Ar_mc_AKGC417L.wav	0
73	203_1p4_Pl_mc_AKGC417L.wav	0
74	203_1p4_Pr_mc_AKGC417L.wav	0
75	203_1p4_Tc_mc_AKGC417L.wav	0
76	203_2p3_Al_mc_AKGC417L.wav	0
77	203_2p3_Ar_mc_AKGC417L.wav	0
78	203_2p3_Pl_mc_AKGC417L.wav	0
79	203_2p3_Pr_mc_AKGC417L.wav	0
80	203_2p3_Tc_mc_AKGC417L.wav	0
81	204_2b5_Al_mc_AKGC417L.wav	0
82	204_2b5_Ar_mc_AKGC417L.wav	0
83	204_2b5_Ll_mc_AKGC417L.wav	0
84	204_7p5_Al_mc_AKGC417L.wav	0
85	204_7p5_Ar_mc_AKGC417L.wav	0
86	204_7p5_Ll_mc_AKGC417L.wav	0
87	204_7p5_Lr_mc_AKGC417L.wav	0
88	204_7p5_Pr_mc_AKGC417L.wav	0
89	204_7p5_Tc_mc_AKGC417L.wav	0
90	205_1b3_Al_mc_AKGC417L.wav	0
91	205_1b3_Ar_mc_AKGC417L.wav	0
92	205_1b3_Ll_mc_AKGC417L.wav	0
93	205_1b3_Lr_mc_AKGC417L.wav	0
94	205_1b3_Pl_mc_AKGC417L.wav	0
95	205_1b3_Pr_mc_AKGC417L.wav	0
96	205_2b2_Pr_mc_AKGC417L.wav	0
97	205_2b3_Al_mc_AKGC417L.wav	0
98	205_2b3_Ar_mc_AKGC417L.wav	0
99	205_2b3_Ll_mc_AKGC417L.wav	0
100	205_2b4_Pl_mc_AKGC417L.wav	0

101	205_3b4_Al_mc_AKGC417L.wav	0
102	205_3b4_Ar_mc_AKGC417L.wav	0
103	205_3b4_Pl_mc_AKGC417L.wav	0
104	205_3b4_Pr_mc_AKGC417L.wav	0
105	205_4b2_Al_mc_AKGC417L.wav	0
106	205_4b2_Ar_mc_AKGC417L.wav	0
107	205_4b2_Lr_mc_AKGC417L.wav	0
108	205_4b2_Pl_mc_AKGC417L.wav	0
109	205_4b2_Pr_mc_AKGC417L.wav	0

Table 1. Input Test Data Files versus Model Prediction

2(a).2 Model Architecture



2(a).3 Training Epochs

```
Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv1d (Conv1D)             (None, 189, 64)           384

 conv1d_1 (Conv1D)           (None, 185, 128)          41088

 max_pooling1d (MaxPooling1D  (None, 92, 128)          0
 )

 conv1d_2 (Conv1D)           (None, 88, 256)           164096

 max_pooling1d_1 (MaxPooling  (None, 44, 256)          0
 1D)

 dropout (Dropout)           (None, 44, 256)           0

 flatten (Flatten)           (None, 11264)             0

 dense (Dense)               (None, 256)               2883840

 dense_1 (Dense)             (None, 3)                 771

=================================================================
Total params: 3,090,179
Trainable params: 3,090,179
Non-trainable params: 0
_________________________________________________________________
None
Epoch 1/50
10/10 [==============================] - 4s 272ms/step - loss: 1.2220 - accuracy: 0.9107 - val_loss: 0.6267 -
val_accuracy: 0.7945
Epoch 2/50
10/10 [==============================] - 2s 242ms/step - loss: 0.4001 - accuracy: 0.9342 - val_loss: 0.2202 -
val_accuracy: 0.9452
Epoch 3/50
10/10 [==============================] - 2s 244ms/step - loss: 0.3969 - accuracy: 0.9608 - val_loss: 0.3400 -
val_accuracy: 0.9452
Epoch 4/50
10/10 [==============================] - 2s 241ms/step - loss: 0.4716 - accuracy: 0.9561 - val_loss: 0.3231 -
val_accuracy: 0.7945
Epoch 5/50
10/10 [==============================] - 2s 244ms/step - loss: 0.2856 - accuracy: 0.9310 - val_loss: 0.2077 -
val_accuracy: 0.9589
Epoch 6/50
10/10 [==============================] - 2s 241ms/step - loss: 0.2014 - accuracy: 0.9702 - val_loss: 0.1633 -
val_accuracy: 0.9452
Epoch 7/50
10/10 [==============================] - 2s 241ms/step - loss: 0.1093 - accuracy: 0.9718 - val_loss: 0.1536 -
val_accuracy: 0.9452
Epoch 8/50
10/10 [==============================] - 2s 241ms/step - loss: 0.1001 - accuracy: 0.9718 - val_loss: 0.1533 -
val_accuracy: 0.9452
Epoch 9/50
10/10 [==============================] - 2s 242ms/step - loss: 0.0952 - accuracy: 0.9718 - val_loss: 0.1386 -
val_accuracy: 0.9452
Epoch 10/50
10/10 [==============================] - 2s 245ms/step - loss: 0.0853 - accuracy: 0.9718 - val_loss: 0.1281 -
val_accuracy: 0.9452
Epoch 11/50
10/10 [==============================] - 2s 241ms/step - loss: 0.0797 - accuracy: 0.9749 - val_loss: 0.1085 -
val_accuracy: 0.9452
Epoch 12/50
10/10 [==============================] - 2s 242ms/step - loss: 0.0729 - accuracy: 0.9734 - val_loss: 0.0993 -
val_accuracy: 0.9589
Epoch 13/50
10/10 [==============================] - 2s 243ms/step - loss: 0.0679 - accuracy: 0.9781 - val_loss: 0.0953 -
val_accuracy: 0.9589
Epoch 14/50
10/10 [==============================] - 2s 242ms/step - loss: 0.0595 - accuracy: 0.9796 - val_loss: 0.1129 -
val_accuracy: 0.9452
Epoch 15/50
```

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10/10 [==============================] - 2s 242ms/step - loss: 0.0638 - accuracy: 0.9765 - val_loss: 0.1074 -
val_accuracy: 0.9452
Epoch 16/50
10/10 [==============================] - 2s 243ms/step - loss: 0.0579 - accuracy: 0.9812 - val_loss: 0.0958 -
val_accuracy: 0.9589
Epoch 17/50
10/10 [==============================] - 2s 241ms/step - loss: 0.0529 - accuracy: 0.9796 - val_loss: 0.0896 -
val_accuracy: 0.9726
Epoch 18/50
10/10 [==============================] - 2s 244ms/step - loss: 0.0536 - accuracy: 0.9796 - val_loss: 0.0896 -
val_accuracy: 0.9589
Epoch 19/50
10/10 [==============================] - 2s 241ms/step - loss: 0.0521 - accuracy: 0.9796 - val_loss: 0.0832 -
val_accuracy: 0.9589
Epoch 20/50
10/10 [==============================] - 2s 242ms/step - loss: 0.0527 - accuracy: 0.9812 - val_loss: 0.0861 -
val_accuracy: 0.9589
Epoch 21/50
10/10 [==============================] - 2s 240ms/step - loss: 0.0532 - accuracy: 0.9749 - val_loss: 0.0881 -
val_accuracy: 0.9589
Epoch 22/50
10/10 [==============================] - 2s 241ms/step - loss: 0.0354 - accuracy: 0.9859 - val_loss: 0.1231 -
val_accuracy: 0.9452
Epoch 23/50
10/10 [==============================] - 2s 242ms/step - loss: 0.0448 - accuracy: 0.9875 - val_loss: 0.0794 -
val_accuracy: 0.9589
Epoch 24/50
10/10 [==============================] - 2s 241ms/step - loss: 0.0441 - accuracy: 0.9812 - val_loss: 0.1112 -
val_accuracy: 0.9589
Epoch 25/50
10/10 [==============================] - 2s 243ms/step - loss: 0.0364 - accuracy: 0.9843 - val_loss: 0.0959 -
val_accuracy: 0.9589
Epoch 26/50
10/10 [==============================] - 2s 242ms/step - loss: 0.0577 - accuracy: 0.9843 - val_loss: 0.1402 -
val_accuracy: 0.9041
Epoch 27/50
10/10 [==============================] - 2s 242ms/step - loss: 0.0621 - accuracy: 0.9796 - val_loss: 0.0791 -
val_accuracy: 0.9726
Epoch 28/50
10/10 [==============================] - 2s 241ms/step - loss: 0.0381 - accuracy: 0.9875 - val_loss: 0.1121 -
val_accuracy: 0.9589
Epoch 29/50
10/10 [==============================] - 2s 242ms/step - loss: 0.0484 - accuracy: 0.9796 - val_loss: 0.0951 -
val_accuracy: 0.9589
Epoch 30/50
10/10 [==============================] - 2s 240ms/step - loss: 0.0384 - accuracy: 0.9812 - val_loss: 0.1102 -
val_accuracy: 0.9589
Epoch 31/50
10/10 [==============================] - 2s 242ms/step - loss: 0.0314 - accuracy: 0.9906 - val_loss: 0.0871 -
val_accuracy: 0.9726
Epoch 32/50
10/10 [==============================] - 2s 240ms/step - loss: 0.0336 - accuracy: 0.9859 - val_loss: 0.0808 -
val_accuracy: 0.9726
Epoch 33/50
10/10 [==============================] - 2s 239ms/step - loss: 0.0322 - accuracy: 0.9843 - val_loss: 0.0786 -
val_accuracy: 0.9726
Epoch 34/50
10/10 [==============================] - 2s 238ms/step - loss: 0.0334 - accuracy: 0.9875 - val_loss: 0.1030 -
val_accuracy: 0.9589
Epoch 35/50
10/10 [==============================] - 2s 240ms/step - loss: 0.0342 - accuracy: 0.9859 - val_loss: 0.0682 -
val_accuracy: 0.9726
Epoch 36/50
10/10 [==============================] - 2s 241ms/step - loss: 0.0326 - accuracy: 0.9828 - val_loss: 0.0646 -
val_accuracy: 0.9726
Epoch 37/50
10/10 [==============================] - 2s 243ms/step - loss: 0.0255 - accuracy: 0.9922 - val_loss: 0.1184 -
val_accuracy: 0.9589
Epoch 38/50
10/10 [==============================] - 2s 246ms/step - loss: 0.0362 - accuracy: 0.9812 - val_loss: 0.0687 -
val_accuracy: 0.9726
Epoch 39/50
10/10 [==============================] - 2s 240ms/step - loss: 0.0469 - accuracy: 0.9812 - val_loss: 0.0699 -
val_accuracy: 0.9726
Epoch 40/50
```

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10/10 [==============================] - 2s 241ms/step - loss: 0.0374 - accuracy: 0.9812 - val_loss: 0.1229 -
val_accuracy: 0.9589
Epoch 41/50
10/10 [==============================] - 2s 240ms/step - loss: 0.0325 - accuracy: 0.9796 - val_loss: 0.0657 -
val_accuracy: 0.9726
Epoch 42/50
10/10 [==============================] - 2s 242ms/step - loss: 0.0267 - accuracy: 0.9812 - val_loss: 0.0540 -
val_accuracy: 0.9726
Epoch 43/50
10/10 [==============================] - 2s 239ms/step - loss: 0.0313 - accuracy: 0.9828 - val_loss: 0.0748 -
val_accuracy: 0.9589
Epoch 44/50
10/10 [==============================] - 2s 243ms/step - loss: 0.0246 - accuracy: 0.9906 - val_loss: 0.0636 -
val_accuracy: 0.9726
Epoch 45/50
10/10 [==============================] - 2s 240ms/step - loss: 0.0319 - accuracy: 0.9890 - val_loss: 0.0954 -
val_accuracy: 0.9452
Epoch 46/50
10/10 [==============================] - 2s 239ms/step - loss: 0.0233 - accuracy: 0.9906 - val_loss: 0.0522 -
val_accuracy: 0.9726
Epoch 47/50
10/10 [==============================] - 2s 240ms/step - loss: 0.0151 - accuracy: 0.9953 - val_loss: 0.0724 -
val_accuracy: 0.9726
Epoch 48/50
10/10 [==============================] - 2s 240ms/step - loss: 0.0199 - accuracy: 0.9906 - val_loss: 0.0633 -
val_accuracy: 0.9726
Epoch 49/50
10/10 [==============================] - 2s 243ms/step - loss: 0.0157 - accuracy: 0.9953 - val_loss: 0.0590 -
val_accuracy: 0.9726
Epoch 50/50
10/10 [==============================] - 2s 242ms/step - loss: 0.0150 - accuracy: 0.9937 - val_loss: 0.0663 -
val_accuracy: 0.9726
```

2(a).4 Performance Metrics of the Model (Respiratory Diseases)

1. Training Results
    a. Accuracy - 99.37%
    b. Loss - 0.0150
2. Validation Results
    a. Accuracy - 97.26%
    b. Loss - 0.0522

2(b). Performance of Model to Classify Crackles / Wheezes / Both / None

The following encoding of classes has been used for data preparation for model training.
0: None
1: Crackles only
2: Wheezes only
3: Both

2(b).1 Target Input Test File Segments versus Model Prediction

Our model works on each segment of the provided test files and infers model predictions for the aforementioned four classes. Since the number of segments in the test data set was ~900, we are showing the results on the first 100 segments in the following table (Table 2).

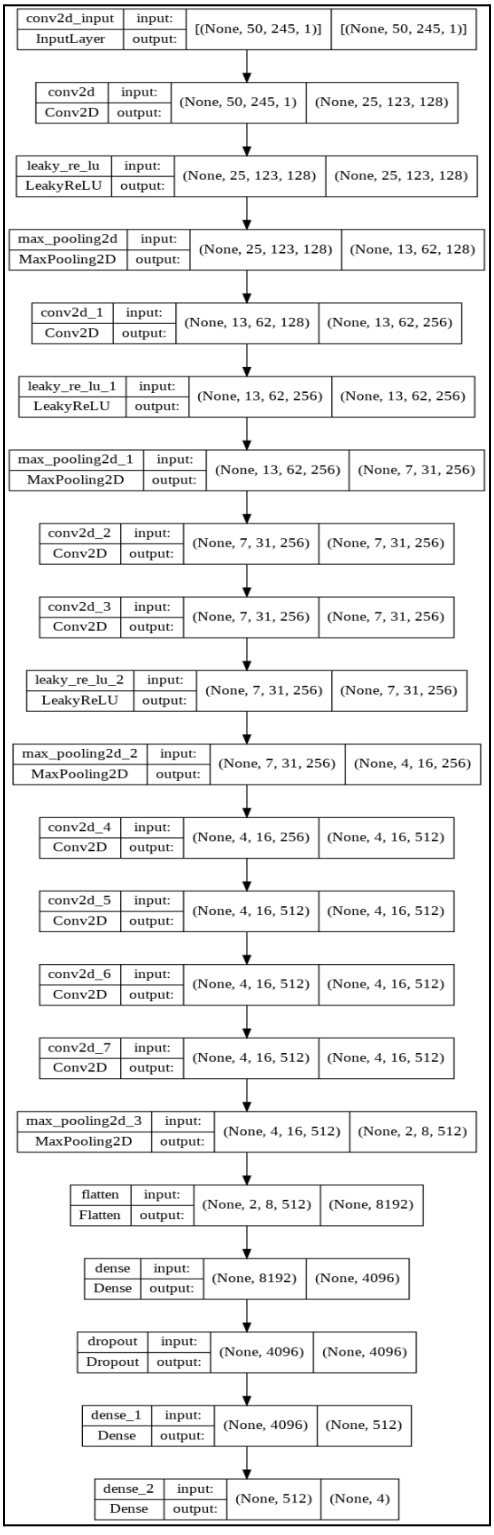
Segment Number	Predicted Class
Segment 1	0
Segment 2	1
Segment 3	0
Segment 4	1
Segment 5	3
Segment 6	2
Segment 7	0
Segment 8	1
Segment 9	1
Segment 10	2
Segment 11	0
Segment 12	2
Segment 13	0
Segment 14	0
Segment 15	1
Segment 16	3
Segment 17	3
Segment 18	0
Segment 19	0
Segment 20	0
Segment 21	0
Segment 22	0
Segment 23	1
Segment 24	2
Segment 25	0
Segment 26	0
Segment 27	0

Segment 28	1
Segment 29	0
Segment 30	1
Segment 31	0
Segment 32	0
Segment 33	3
Segment 34	0
Segment 35	0
Segment 36	1
Segment 37	0
Segment 38	1
Segment 39	1
Segment 40	0
Segment 41	0
Segment 42	2
Segment 43	0
Segment 44	1
Segment 45	1
Segment 46	3
Segment 47	0
Segment 48	0
Segment 49	0
Segment 50	0
Segment 51	0
Segment 52	1
Segment 53	2
Segment 54	0
Segment 55	0
Segment 56	0
Segment 57	3
Segment 58	1
Segment 59	0
Segment 60	0
Segment 61	0
Segment 62	0
Segment 63	1
Segment 64	1
Segment 65	1
Segment 66	0

Segment 67	1
Segment 68	2
Segment 69	3
Segment 70	3
Segment 71	0
Segment 72	1
Segment 73	0
Segment 74	1
Segment 75	2
Segment 76	0
Segment 77	2
Segment 78	1
Segment 79	2
Segment 80	0
Segment 81	0
Segment 82	0
Segment 83	0
Segment 84	1
Segment 85	0
Segment 86	0
Segment 87	0
Segment 88	3
Segment 89	1
Segment 90	0
Segment 91	0
Segment 92	0
Segment 93	0
Segment 94	0
Segment 95	3
Segment 96	3
Segment 97	0
Segment 98	0
Segment 99	1
Segment 100	0

Table 2. Input Test Data Segments versus Model Prediction

2(b).2 Model Architecture



2(b).3 Training Epochs

```
Epoch 1/50
/usr/local/lib/python3.7/dist-packages/ipykernel_launcher.py:5: UserWarning: `Model.fit_generator` is deprecated
and will be removed in a future version. Please use `Model.fit`, which supports generators.
  """
31/31 [==============================] - 3s 80ms/step - loss: 1.3400 - acc: 0.3216 - val_loss: 1.3308 - val_acc:
0.2734
Epoch 2/50
31/31 [==============================] - 2s 73ms/step - loss: 1.2688 - acc: 0.4032 - val_loss: 1.2446 - val_acc:
0.5234
Epoch 3/50
31/31 [==============================] - 2s 73ms/step - loss: 1.1938 - acc: 0.4546 - val_loss: 1.1883 - val_acc:
0.4609
Epoch 4/50
31/31 [==============================] - 2s 73ms/step - loss: 1.1153 - acc: 0.5086 - val_loss: 1.2803 - val_acc:
0.4922
Epoch 5/50
31/31 [==============================] - 2s 73ms/step - loss: 1.0499 - acc: 0.5479 - val_loss: 1.1103 - val_acc:
0.5391
Epoch 6/50
31/31 [==============================] - 2s 73ms/step - loss: 0.9580 - acc: 0.5927 - val_loss: 0.9889 - val_acc:
0.6172
Epoch 7/50
31/31 [==============================] - 2s 74ms/step - loss: 0.8963 - acc: 0.6134 - val_loss: 1.0325 - val_acc:
0.5938
Epoch 8/50
31/31 [==============================] - 2s 74ms/step - loss: 0.8476 - acc: 0.6502 - val_loss: 0.8898 - val_acc:
0.6250
Epoch 9/50
31/31 [==============================] - 2s 75ms/step - loss: 0.7783 - acc: 0.6784 - val_loss: 0.9622 - val_acc:
0.5938
Epoch 10/50
31/31 [==============================] - 2s 76ms/step - loss: 0.7334 - acc: 0.6920 - val_loss: 0.8936 - val_acc:
0.6797
Epoch 11/50
31/31 [==============================] - 2s 76ms/step - loss: 0.6960 - acc: 0.7082 - val_loss: 0.8631 - val_acc:
0.6562
Epoch 12/50
31/31 [==============================] - 2s 76ms/step - loss: 0.6483 - acc: 0.7389 - val_loss: 0.6767 - val_acc:
0.7578
Epoch 13/50
31/31 [==============================] - 2s 76ms/step - loss: 0.6112 - acc: 0.7651 - val_loss: 0.9240 - val_acc:
0.6562
Epoch 14/50
31/31 [==============================] - 2s 76ms/step - loss: 0.5831 - acc: 0.7596 - val_loss: 0.8790 - val_acc:
0.6484
Epoch 15/50
31/31 [==============================] - 2s 77ms/step - loss: 0.5622 - acc: 0.7742 - val_loss: 0.7745 - val_acc:
0.6953
Epoch 16/50
31/31 [==============================] - 2s 76ms/step - loss: 0.5405 - acc: 0.7883 - val_loss: 0.8632 - val_acc:
0.6406
Epoch 17/50
31/31 [==============================] - 2s 77ms/step - loss: 0.5013 - acc: 0.7999 - val_loss: 0.8341 - val_acc:
0.6875
Epoch 18/50
31/31 [==============================] - 2s 77ms/step - loss: 0.5363 - acc: 0.7999 - val_loss: 0.6592 - val_acc:
0.7344
Epoch 19/50
31/31 [==============================] - 2s 78ms/step - loss: 0.4855 - acc: 0.8130 - val_loss: 0.6915 - val_acc:
0.7109
Epoch 20/50
31/31 [==============================] - 2s 77ms/step - loss: 0.4494 - acc: 0.8317 - val_loss: 0.6444 - val_acc:
0.7500
Epoch 21/50
31/31 [==============================] - 2s 77ms/step - loss: 0.4511 - acc: 0.8291 - val_loss: 0.6812 - val_acc:
0.7422
Epoch 22/50
31/31 [==============================] - 2s 77ms/step - loss: 0.4111 - acc: 0.8377 - val_loss: 0.7132 - val_acc:
0.7500
Epoch 23/50
31/31 [==============================] - 2s 77ms/step - loss: 0.4047 - acc: 0.8438 - val_loss: 0.6795 - val_acc:
0.7500
Epoch 24/50
```

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31/31 [==============================] - 2s 78ms/step - loss: 0.3735 - acc: 0.8604 - val_loss: 0.7412 - val_acc:
0.6953
Epoch 25/50
31/31 [==============================] - 2s 78ms/step - loss: 0.3647 - acc: 0.8569 - val_loss: 0.7438 - val_acc:
0.7266
Epoch 26/50
31/31 [==============================] - 2s 78ms/step - loss: 0.3614 - acc: 0.8604 - val_loss: 0.6785 - val_acc:
0.7500
Epoch 27/50
31/31 [==============================] - 2s 79ms/step - loss: 0.3545 - acc: 0.8589 - val_loss: 0.7352 - val_acc:
0.7422
Epoch 28/50
31/31 [==============================] - 2s 78ms/step - loss: 0.3200 - acc: 0.8720 - val_loss: 0.7623 - val_acc:
0.7422
Epoch 29/50
31/31 [==============================] - 2s 79ms/step - loss: 0.2955 - acc: 0.8846 - val_loss: 0.8264 - val_acc:
0.7500
Epoch 30/50
31/31 [==============================] - 2s 78ms/step - loss: 0.3393 - acc: 0.8690 - val_loss: 0.6915 - val_acc:
0.7109
Epoch 31/50
31/31 [==============================] - 2s 78ms/step - loss: 0.3451 - acc: 0.8634 - val_loss: 0.8826 - val_acc:
0.7344
Epoch 32/50
31/31 [==============================] - 2s 77ms/step - loss: 0.2975 - acc: 0.8795 - val_loss: 0.6714 - val_acc:
0.7812
Epoch 33/50
31/31 [==============================] - 2s 78ms/step - loss: 0.2800 - acc: 0.8911 - val_loss: 0.7379 - val_acc:
0.7578
Epoch 34/50
31/31 [==============================] - 2s 78ms/step - loss: 0.2533 - acc: 0.8987 - val_loss: 0.6159 - val_acc:
0.7969
Epoch 35/50
31/31 [==============================] - 2s 77ms/step - loss: 0.2648 - acc: 0.8962 - val_loss: 0.6328 - val_acc:
0.7812
Epoch 36/50
31/31 [==============================] - 2s 77ms/step - loss: 0.2441 - acc: 0.9007 - val_loss: 0.8007 - val_acc:
0.7422
Epoch 37/50
31/31 [==============================] - 2s 77ms/step - loss: 0.2643 - acc: 0.8952 - val_loss: 0.7857 - val_acc:
0.7578
Epoch 38/50
31/31 [==============================] - 2s 77ms/step - loss: 0.2535 - acc: 0.8982 - val_loss: 0.7922 - val_acc:
0.7500
Epoch 39/50
31/31 [==============================] - 2s 77ms/step - loss: 0.2222 - acc: 0.9098 - val_loss: 0.6989 - val_acc:
0.7422
Epoch 40/50
31/31 [==============================] - 2s 77ms/step - loss: 0.2446 - acc: 0.9042 - val_loss: 0.7967 - val_acc:
0.7344
Epoch 41/50
31/31 [==============================] - 2s 77ms/step - loss: 0.2332 - acc: 0.9128 - val_loss: 0.7096 - val_acc:
0.7344
Epoch 42/50
31/31 [==============================] - 2s 77ms/step - loss: 0.1971 - acc: 0.9194 - val_loss: 0.6084 - val_acc:
0.7656
Epoch 43/50
31/31 [==============================] - 2s 77ms/step - loss: 0.1884 - acc: 0.9244 - val_loss: 0.6919 - val_acc:
0.8047
Epoch 44/50
31/31 [==============================] - 2s 77ms/step - loss: 0.1765 - acc: 0.9309 - val_loss: 0.7407 - val_acc:
0.7969
Epoch 45/50
31/31 [==============================] - 2s 77ms/step - loss: 0.1725 - acc: 0.9365 - val_loss: 0.8190 - val_acc:
0.7891
Epoch 46/50
31/31 [==============================] - 2s 77ms/step - loss: 0.1739 - acc: 0.9355 - val_loss: 0.8385 - val_acc:
0.7656
Epoch 47/50
31/31 [==============================] - 2s 76ms/step - loss: 0.1753 - acc: 0.9294 - val_loss: 0.9868 - val_acc:
0.7422
Epoch 48/50
31/31 [==============================] - 2s 77ms/step - loss: 0.1554 - acc: 0.9415 - val_loss: 0.7711 - val_acc:
0.7812
Epoch 49/50
```

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31/31 [==============================] - 2s 77ms/step - loss: 0.1738 - acc: 0.9335 - val_loss: 0.8268 - val_acc:
0.7578
Epoch 50/50
31/31 [==============================] - 2s 77ms/step - loss: 0.1563 - acc: 0.9420 - val_loss: 0.9001 - val_acc:
0.7344
```

2(b).4 Performance Metrics of the Model (Crackles / Wheezes / Both / None)

1. Training Results
    a. Accuracy - 94.20%
    b. Loss - 0.1563
2. Validation Results
    a. Accuracy - 80.47%
    b. Loss - 0.6159