LIE DETECTION USING AUDIO CLASSIFICATION (CNN)

Team Members:

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Report submitted for the
Final Project Review of

Course Code: CSE3055
Deep Learning

Slot: F1 Slot

Professor: Dr.W.B. Vasantha

1. Introduction:

Lying is among the most sophisticated and demanding accomplishments of the human brain. The lie detection is until now posing a problem in recent research which aims to develop a non-contact application in order to estimate physiological changes.

With a growing interest in security, the desire for automated lie detection has long been an endeavour sought after for its applications to court decisions, law enforcement, etc. Hearings of witnesses and defendants play a crucial role when reaching court trial decisions. Given the high-stake nature of trial outcomes, implementing accurate and effective computational methods to evaluate the honesty of court testimonies can offer valuable support during the decision-making process.

We put forth our idea where we use real-life trial data and convert it to audio files to detect the change in modality while deception is taking place. We explore the use of verbal modalities to build a deception detection system using speech that aims to discriminate between truthful and deceptive statements provided by defendants and witnesses.

We use audio instead of videographic data as it will avoid numerous discrepancies that can occur while collecting data and it will avoid physical bias. It also helps reduce complexity of the network which will in turn help in making it faster and being able to adapt better to our data.

2. Literature Review Summary Table

Authors and Year (Reference)	***Title (Study)***	***Concept / Theoretical model/ Framework***	***Methodology used/ Implementation***	***Dataset details/ Analysis***	***Relevant Finding***	***Limitations/ Future Research/ Gaps identified***
Serban Mihalache, Gheorghe Pop , Dragos Burileanu (2019)	*Introducing the RODeCAR Database for Deceptive Speech Detection*	*Database of Romanian criminals labelled to if they were lying or not.*	-	*5 hours of recorded material, with 15 speakers.*	*How data is collected and labelled as truth and lies and how skewed data can cause discrimination .*	*Small dataset with very skewed data as it contains more males then females*
Gangeshwar Krishnamurthy, Soujanya Poria, Erik Cambria, Navonil Majumder (2018)	*A Deep Learning Approach for Multimodal Deception Detection*	*Multimodal neural network by combining video, audio, text, microexpressions,*	*Uses multiple modals and combines them to give an output of whether they are lying or not.*	*Real life deception dataset*	*Unique way to use multiple mediums of input to gain optimal output.*	*Too time taking and complex. Will be susceptible to profiling based on race, sex.*
Nuria Rodriguez-Diaz, Decky Aspandi , Federico M. Sukno, Xavier Binefa (2021)	*Machine Learning-Based Lie Detector Applied to a Novel Annotated Game Dataset*	*A research where people are made to play a game in which they are forced to lie convincingly called box of lies.*	*Made participants play a game called box of lies where they have to describe an object kept in front of them and the user has to guess whether they were lying or not.*	*Contains 26 recordings with 18 faces, and 15566 frames*	*Unique way to collect data for this subject.*	*Uses video which again leads to racial bias, also uses machine learning methods which won't work as well when compared to deep learning models. Dataset is also too small to make any significant learnings.*

Sushma Venkatesh, Raghavendra Ramachandra, Patrick Bours, (2020)	*Video Based Deception Detection Using Deep Recurrent Convolutional Neural Network*	*Using Deep recurrent convolutional networks on video data for deception detection*	*Used a combination of googleNet CNNs, and bidirectional LSTM neural networks to predict deception detection*	*121 deceptive and truthful videos*	*Usage of a combination of CNNs and RNNs can be done to get the best of both worlds.*	*Uses video which causes racial and gender bias and is very difficult to capture appropriate data for.*
Nidhi Srivastava, Sipi Dubey	*Deception detection using artificial neural network and support vector machine*	*Using multiple physical features to predict deception*	*Uses features like Mel Frequency Cepstrum Coefficient, Energy, Zero Crossing Rate, Fundamental Frequency and frame function of speech signal and physical values like Heart Beat, Blood Pressure and Respiratory Rate to predict deception*	*Dataset contains 50 training examples of the aforementioned features along with audio.*	*How physical features effect deception*	*Hard to have accurate apparatus for measuring physical features, uses primitive prediction techniques.*

3. Objective of the project:

The main objective of this project is to use the verbal/speech modalities to detect deception adopted by humans. The implementation of the deep learning methods will surely outperform the human capabilities to identify deceit.

4. Innovation component in the project:

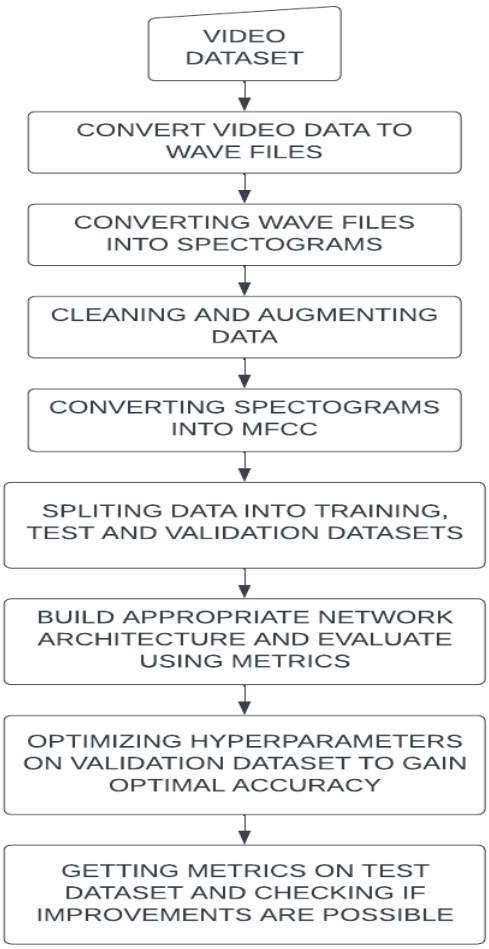
The most innovative part of our project is the type of data used i.e. audio/speech. If we use video data then it can lead to racial profiling and numerous other physical biases which will give us numerous false positives and negatives. It also makes collection of data easier and more uniform and is able to include and adapt to more outliers. Moreover, in case of video data, too many different dependencies like angle, lighting, etc. come into picture which can skew the data.

The modules in the project are as follows:

- IMPORTING DATA
- CONVERTING TO SPECTOGRAM
- CONVERTING TO MFCC
- CLEANING AND AUGMENTATION OF DATA
- BUILDING NETWORK ARCHITECTURE
- TRAINING NETWORK ARCHITECTURE ON DATA
- DECIDING EVALUATION METRICS AND TESTING

5. Work done and implementation

a. Methodology adapted:



Hardware

- CPU
- GPU
- RAM

Software

- Python (PyTorch, Keras, TensorFlow, Sci-Py)
- Jupyter notebook
- Github

b. Dataset used:

a. **Where from you are taking your dataset?**

Dataset: https://web.eecs.umich.edu/~mihalcea/downloads.html#RealLifeDeception

b. **Is your project based on any other reference project (Stanford Univ. or MIT)?**

Reference Project: https://www.mdpi.com/1999-5903/14/1/2/pdf

c. **How does your project differ from the reference project?**

The reference project uses basic Machine Learning Model. We plan to use Deep Learning techniques that shows improved performance on other audio classification problems.

c. Tools used:

Jupyter Notebook, Python, PyTorch, Keras, TensorFlow, Sci-Py.

Justification for using above tools:

One of the software that we have used is **Jupyter Notebook**. The main advantage of Jupyter Notebook is its modularity approach. We can run cell by cell to better get an understanding of what the code does.

Python is an advanced programming language. It works with less code, doesn't demand from the users to put a lot of code and thus reduces the number of tasks involved. Python has many in-built libraries that eases the work and the time and space complexity of any algorithm. It is open-source and has a vast community of programmers using python for a long time. It is the most sought-after tool by Data Scientists, AI/ML experts and Graphic Designers.

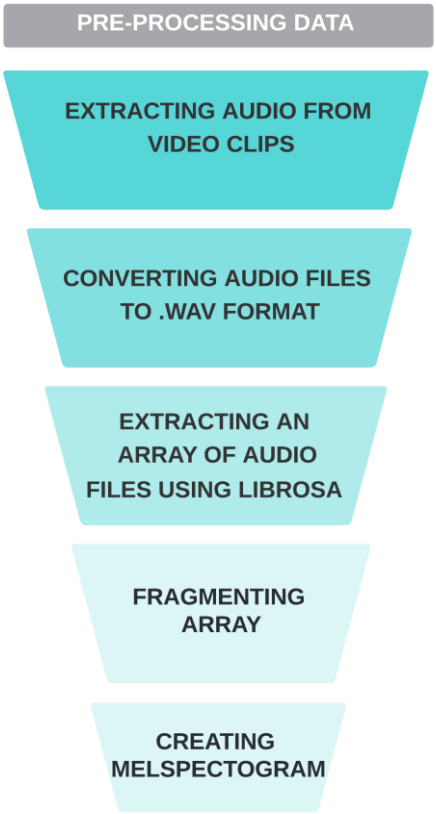
PyTorch offers easy to use API; hence it is considered to be very simple to operate and runs on Python. The code execution in this framework is quite easy.

Keras provides numerous pre-trained models. There are models besides the pre-trained weights. These models help users to simplify their tasks.

TensorFlow has better computational graph visualizations. It helps us execute subpart of a graph which gives it an upper hand as we can introduce and retrieve discrete data.

SciPy provides a plethora of special functions, including Bessel functions (and routines for finding their zeros, derivatives, and integrals), error functions, the gamma function, Legendre, Laguerre, and Hermite polynomials (and other polynomial functions), Mathieu functions, many statistical functions, and a number of other functions.

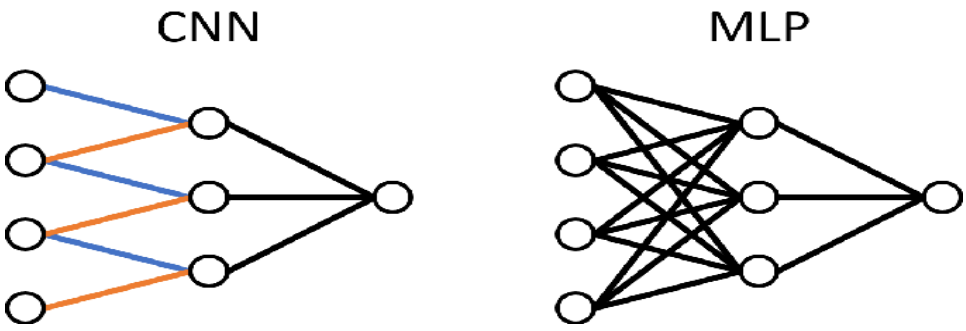
d. Pre-processing involved:



e. Models used:

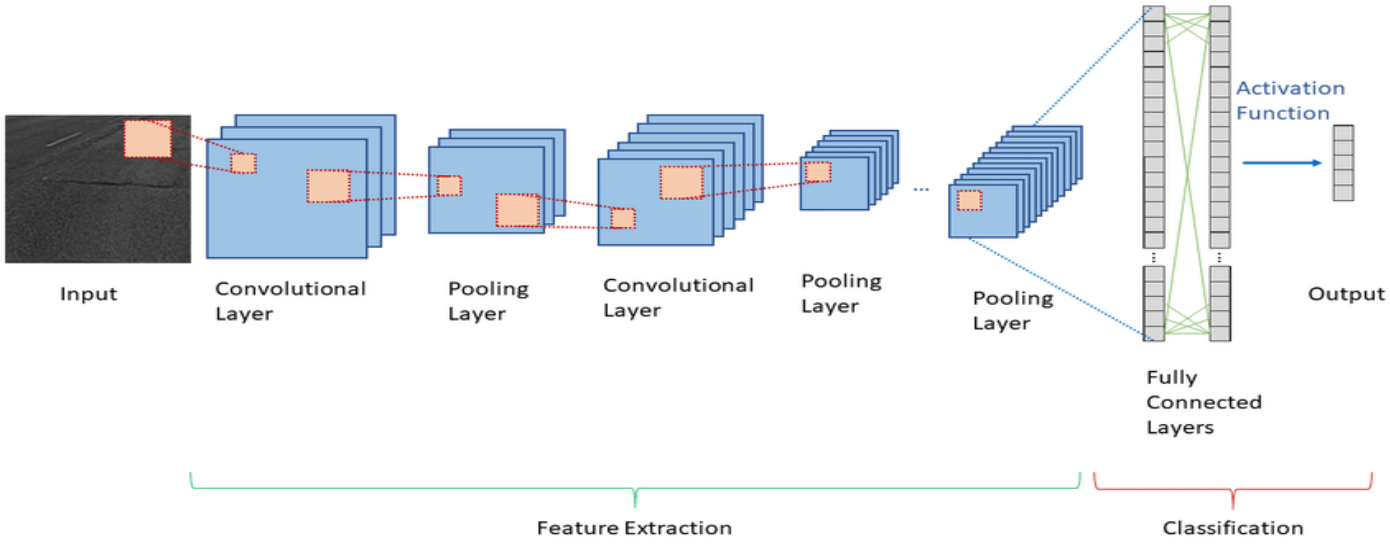
We used a CNN architecture as CNNs are ideal for image classification. In this problem we have converted the audio files into Mel Spectrograms which are in the form of graphs. Therefore, Convolutional Neural Networks are appropriate to extract features from the Mel Spectrograms.

CNNs take tensors as input, therefore they **understand spatial relations better** than multi layered perceptron. Convolutional Layers are not densely connected; therefore, it is easier to learn functions with high-dimensional inputs.



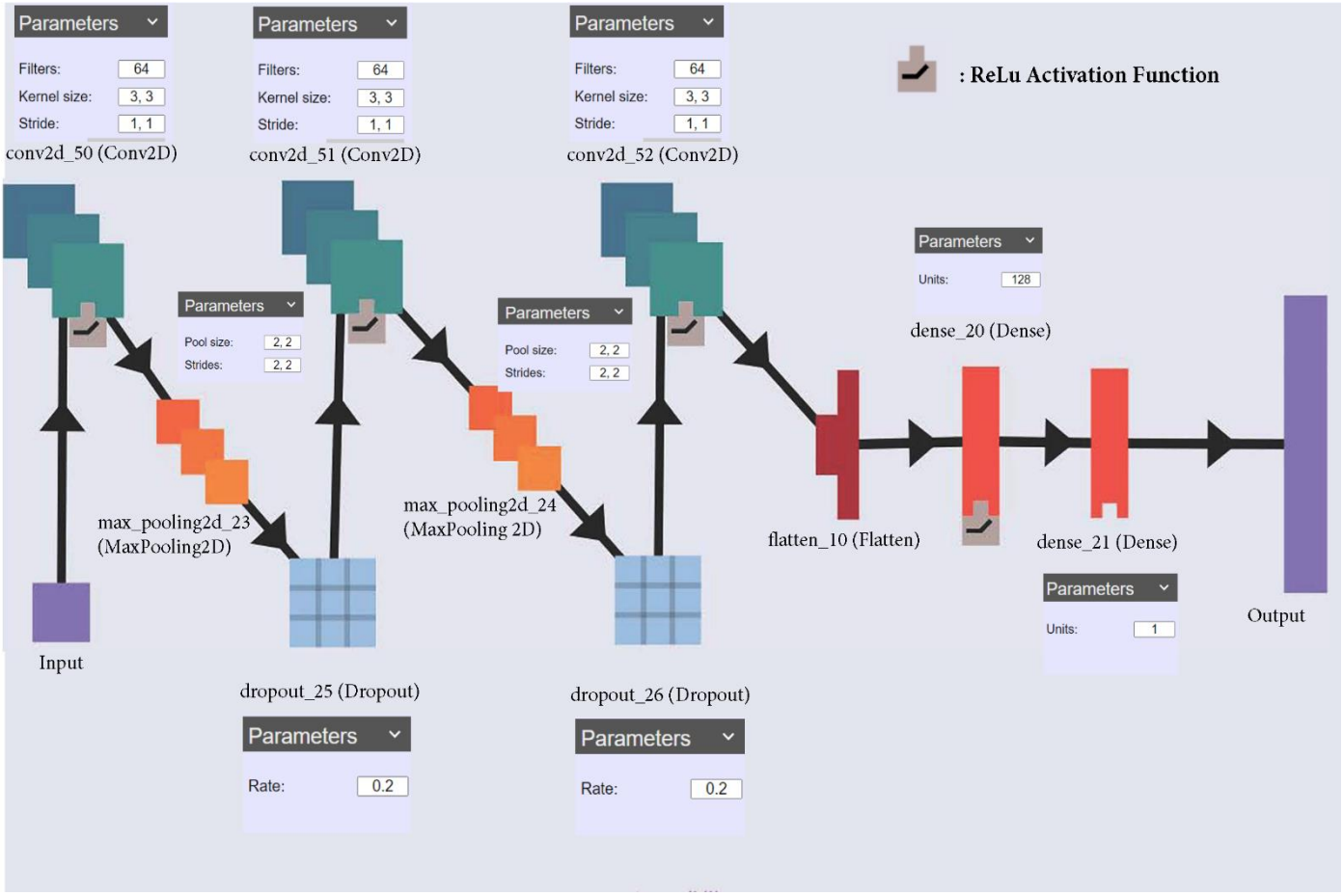
Class imbalance was not present in the dataset as we had equal number of positive and negative class samples.

f. Model Architecture:



g. Screenshot and Demo along with Visualization (For results):

Visualization of our proposed model:



In [ ]:
```
!pip install librosa
```

In [1]:
```
import librosa
track_path = 'C:/Users/Achinthya/RealLifeDeceptionDetection.2016/Real-life_Deception_Detection_2016/Clips/Dataset/Deceptive wav/trial_lie
y,sr = librosa.load(track_path,sr=10000)
print(y)
```

```
[ 0.          0.          0.         ... -0.00027323  0.00031922
  0.        ]
```

In [2]:
```
len(y)
```

Out[2]:
```
169867
```

In [3]:
```
# cut each song in pieces of 100.000 before doing anything else

def cut_track(track):
  start = 0
  end = len(track)

  track_pieces = []

  while start + 10000 < end:
    track_pieces.append(track[start:start+10000])

    start += 10000

  return track_pieces
x = cut_track(track_path)
```

In [4]:
```
def prepare_track(track_path):
  list_matrices = []
  y,sr = librosa.load(track_path,sr=22050)
  track_pieces = cut_track(y)
  for track_piece in track_pieces:
    melspect = librosa.feature.melspectrogram(track_piece)
    list_matrices.append(melspect)
  return list_matrices
prepare_track(track_path)
```

```
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[0.         0.         0.         ... 0.04385633 0.04152411 0.03988262] as keywo
rd args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[0.03918878 0.03729123 0.03665893 ... 0.03373447 0.02443952 0.0209892 ] as keywo
rd args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[ 0.01215388  0.00728973  0.00393789 ...  0.00177856  0.00061905
 -0.00057496] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
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 -0.0029973 ] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[-0.0036039  -0.00347046 -0.00273612 ... -0.00887388 -0.00909347
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  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[-0.00800803 -0.00788274 -0.00760331 ...  0.00201122  0.00106967
 -0.00051392] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
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  0.00951622] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
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rd args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
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rd args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
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  melspect = librosa.feature.melspectrogram(track_piece)
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  0.01872673] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
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rd args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
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rd args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
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  melspect = librosa.feature.melspectrogram(track_piece)
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  melspect = librosa.feature.melspectrogram(track_piece)
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  melspect = librosa.feature.melspectrogram(track_piece)
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  melspect = librosa.feature.melspectrogram(track_piece)
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  melspect = librosa.feature.melspectrogram(track_piece)
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  melspect = librosa.feature.melspectrogram(track_piece)
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  melspect = librosa.feature.melspectrogram(track_piece)
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  melspect = librosa.feature.melspectrogram(track_piece)
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rd args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
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  melspect = librosa.feature.melspectrogram(track_piece)
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  melspect = librosa.feature.melspectrogram(track_piece)
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  melspect = librosa.feature.melspectrogram(track_piece)
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  melspect = librosa.feature.melspectrogram(track_piece)
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  melspect = librosa.feature.melspectrogram(track_piece)
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```

```
  melspect = librosa.feature.melspectrogram(track_piece)
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  0.0015768 ] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
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  melspect = librosa.feature.melspectrogram(track_piece)
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rd args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
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 -9.6500495e-05 -5.8404822e-04] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
```

Out[4]:
```
[array([[1.4168302e-04, 1.7406291e-01, 1.0838628e+00, ..., 2.6204747e-03,
         1.8475705e-03, 2.2828565e-03],
        [3.4976698e-04, 1.3822722e-01, 5.0364679e-01, ..., 1.4502377e-03,
         2.0035682e-03, 1.3310541e-03],
        [4.1362896e-04, 2.8552005e-02, 4.4870436e-02, ..., 1.5109607e-03,
         1.6421915e-03, 7.0596896e-03],
        ...,
        [3.0200503e-08, 1.5616090e-06, 2.8406605e-06, ..., 2.3309889e-05,
         1.5274411e-05, 3.5173776e-05],
        [8.5566541e-09, 6.0994847e-07, 1.1662837e-06, ..., 6.7933652e-06,
         7.3783517e-06, 3.1383723e-05],
        [1.2112352e-09, 6.2982025e-08, 1.2065361e-07, ..., 6.0202751e-07,
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        [9.43028927e-03, 4.87080310e-03, 1.82146311e-03, ...,
         5.43582533e-03, 5.48013300e-03, 5.15192002e-03],
        [8.22653435e-03, 3.98690905e-03, 3.48148937e-03, ...,
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        ...,
        [4.72711727e-05, 2.58448272e-05, 6.41646284e-06, ...,
         2.06595614e-05, 1.46556613e-05, 3.08550589e-05],
        [4.67279024e-05, 1.34615648e-05, 1.21632377e-06, ...,
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        [3.82041617e-05, 9.55202813e-06, 6.75937670e-08, ...,
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```

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```

In [5]:

```
# all tracks will be the X features and deceptive will be the target y
all_tracks = []
deceptive = []
truth = []
for i in range(1,61):
    if i<10:
        truth.append('trial_truth_00' + str(i) + '.wav')
    else:
        truth.append('trial_truth_0' + str(i) + '.wav')
print(truth)
```

```
['trial_truth_001.wav', 'trial_truth_002.wav', 'trial_truth_003.wav', 'trial_truth_004.wav', 'trial_truth_005.wav', 'trial_truth_006.wa
v', 'trial_truth_007.wav', 'trial_truth_008.wav', 'trial_truth_009.wav', 'trial_truth_010.wav', 'trial_truth_011.wav', 'trial_truth_012.
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'trial_truth_060.wav']
```

In [6]:

```
# add all the songs that are in the truth folder
for track in truth:
    track_pieces = prepare_track('C:/Users/Achinthya/RealLifeDeceptionDetection.2016/Real-life_Deception_Detection_2016/Clips/Dataset/Trut
    all_tracks += track_pieces
    deceptive += ([1]*len(track_pieces))
```

```
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[-1.3051817e-07  1.6417982e-07 -1.9964263e-07 ... -3.6383372e-02
 -3.7700959e-02 -3.7851024e-02] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[-0.03518446 -0.02330992 -0.01138742 ... -0.03218677 -0.02851193
 -0.0287147 ] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[-0.03068241 -0.03436081 -0.03442284 ... -0.00675019 -0.01365155
 -0.0040125 ] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[-0.00927818 -0.004684    0.0011768  ...  0.03186605  0.02740845
  0.02166129] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[0.01600906 0.01341374 0.01148094 ... 0.00429693 0.00400456 0.00381167] as keywo
rd args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[ 0.00296905  0.00366059  0.0036471  ...  0.20970196 -0.19113937
  0.03692206] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[ 0.0669149  -0.06216848  0.05249475 ... -0.00684921 -0.00754292
 -0.00732227] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[-0.0078333  -0.00860411 -0.00981659 ... -0.00346277 -0.00329961
 -0.00295773] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[-0.00365278 -0.00450657 -0.00497447 ... -0.00457413 -0.01003675
 -0.00571163] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[-6.9389441e-03 -7.9264576e-03 -9.1842252e-05 ... -3.8658887e-02
 -2.4509164e-02 -1.0693083e-02] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[-0.0011144   0.02413813  0.0439708  ... -0.02610135 -0.02824645
 -0.02774856] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[-0.02897704 -0.02972266 -0.02458643 ...  0.00153088  0.00034971
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  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[0.00126217 0.00055563 0.00149039 ... 0.02114982 0.02179725 0.01817724] as keywo
rd args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[ 0.02072279  0.01880462  0.01960891 ...  0.01867255 -0.05137243
  0.06363906] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[-0.06998749 -0.00272915  0.06057694 ...  0.03554693  0.04013142
  0.04516481] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[ 0.05212578  0.05704108  0.06283793 ...  0.00874337 -0.00548424
 -0.02097335] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[ 0.0168532  -0.01903278 -0.01428523 ... -0.00305426 -0.00393005
 -0.00375461] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[-0.00530035 -0.00462424 -0.00253113 ... -0.00768732  0.01702993
  0.03950118] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[ 0.05873254  0.07171803  0.07853246 ... -0.00063438 -0.00048389
 -0.00093423] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[-0.00043866  0.00016654  0.00075382 ... -0.01232344 -0.00712316
 -0.00633875] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[-0.00654707 -0.00536416 -0.00457549 ...  0.01575961  0.01040722
  0.01467028] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[0.01229643 0.01311855 0.01444551 ... 0.05310458 0.05636818 0.05759151] as keywo
rd args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[ 0.06136849  0.06866907  0.07785205 ... -0.00928347 -0.0098548
 -0.01517221] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[ 0.00629216 -0.01845688 -0.00854046 ...  0.03049803  0.02815354
  0.03514579] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[0.04404604 0.04830612 0.05434464 ... 0.02117199 0.0217048  0.0184967 ] as keywo
rd args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[ 0.01483579  0.01182927  0.0052888  ... -0.03495705 -0.05555373
 -0.07248911] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[-0.08998133 -0.10433684 -0.11669414 ... -0.00019851  0.0008454
  0.00183137] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[ 0.00091666  0.00067188 -0.00415681 ...  0.02970714  0.04920175
  0.06039424] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[0.06557685 0.06212458 0.05366278 ... 0.05017991 0.0376865  0.02050303] as keywo
rd args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[ 0.00486495 -0.01139446 -0.02044952 ... -0.00257806 -0.00352165
 -0.00302814] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[-0.00741713 -0.00754696 -0.00268231 ...  0.01868453  0.01668991
  0.01764969] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[ 0.01800659  0.01711135  0.01854929 ... -0.04690017 -0.04898136
 -0.04805248] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[-0.05013551 -0.05209277 -0.05318363 ...  0.00048608  0.00096151
  0.00195472] as keyword args. From version 0.10 passing these as positional arguments will result in an error
```

```
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[ 0.00367289  0.00479166  0.00528631 ... -0.00014339 -0.00044455
 -0.00078723] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[-0.00120405 -0.00194602 -0.00274586 ...  0.00896266  0.00073677
  0.00402262] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[0.01875941 0.00205411 0.01201885 ... 0.02441378 0.02128026 0.01597345] as keywo
rd args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[ 0.01444353  0.01502534  0.01099797 ... -0.02092582  0.00446086
 -0.00114734] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[-0.00682693 -0.00741957 -0.0062954  ...  0.00453015  0.00508475
  0.00541519] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[0.0053949  0.00541162 0.00521586 ... 0.0693907  0.0693085  0.07134949] as keywo
rd args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[0.06261099 0.06991206 0.06808199 ... 0.0461311  0.05592012 0.05536511] as keywo
rd args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[ 0.05766566  0.05842471  0.04994669 ... -0.00055443 -0.00031909
  0.00074917] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[0.00182116 0.00258622 0.0030668  ... 0.002523   0.0031135  0.00304626] as keywo
rd args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[ 0.00290311  0.00316972  0.0033398  ... -0.08030307 -0.07351546
 -0.06984022] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[-0.06517716 -0.06175554 -0.06160336 ...  0.00141777  0.0016867
  0.0018847 ] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[ 0.00247676  0.00201641  0.00229458 ... -0.00598007 -0.0084722
 -0.00748801] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[-0.00748241 -0.00754578 -0.00311564 ... -0.00085917 -0.00041
  0.00017885] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[ 0.00078177  0.00141904  0.0019043  ... -0.06289268 -0.06324832
 -0.06610506] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[-0.0690534  -0.07530719 -0.08288039 ...  0.00923886 -0.0131247
 -0.00220995] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[-0.01755097  0.01647202 -0.00947374 ... -0.0060979  -0.00764272
 -0.00891357] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[-0.01100924 -0.01252174 -0.01208445 ... -0.00199597  0.00044483
  0.01043518] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[ 0.01391467  0.01910381  0.02442114 ... -0.07347386 -0.07560768
 -0.07483852] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[-0.07430387 -0.07379549 -0.07409975 ...  0.01527186  0.0223219
  0.02632352] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[ 0.03044096  0.03605224  0.03534193 ... -0.00144153 -0.00184327
 -0.00223673] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[-0.00232265 -0.00224103 -0.00201029 ... -0.00159089 -0.00134381
 -0.00112094] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[-6.9452962e-04 -3.2659591e-04 -4.5456029e-05 ...  2.6374136e-03
  3.2920577e-03  4.0255827e-03] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[ 0.00493227  0.00585172  0.00567185 ... -0.00399668 -0.00283091
 -0.00159242] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[-0.00074602  0.00031488  0.00097687 ...  0.01208071  0.01146298
  0.01003952] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[ 0.00919357  0.00879969  0.00945969 ... -0.00092883 -0.0012112
 -0.00131781] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[-0.00123232 -0.00010777  0.00289607 ...  0.02665363  0.02544381
  0.02819324] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[0.02652582 0.02428033 0.02653923 ... 0.00134697 0.00155829 0.00168759] as keywo
rd args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[ 1.2392938e-03  7.7018316e-04 -8.3922700e-05 ... -3.2893009e-03
 -3.1850680e-03 -3.3987891e-03] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[-0.00372595 -0.00369246 -0.00310979 ...  0.04514158  0.02791759
 -0.04892111] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[ 2.0996952e-02  4.2115126e-02 -4.0243907e-05 ...  1.0077675e-02
  8.9242086e-03  1.1901000e-02] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[ 0.01112285  0.01647191  0.01423898 ... -0.06974514 -0.07508356
 -0.07857033] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[-0.08357358 -0.0871664  -0.09448951 ... -0.01872376 -0.01916479
 -0.01969599] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[-0.01993033 -0.02055195 -0.02098089 ...  0.01943625  0.01970042
  0.02108999] as keyword args. From version 0.10 passing these as positional arguments will result in an error
```

```
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[-0.01530707 -0.0101653  -0.0035947  ... -0.01507556 -0.01202203
 -0.01078758] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[-0.00123352  0.01787328  0.04348991 ...  0.00157734  0.00123071
  0.00088763] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[0.00190389 0.00178853 0.00054446 ... 0.00577285 0.00393778 0.00379838] as keywo
rd args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[ 0.00257677  0.00044454 -0.00034117 ...  0.01985855  0.0492731
  0.07814874] as keyword args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
<ipython-input-4-f8bf20af5acb>:6: FutureWarning: Pass y=[0.1061855  0.12440126 0.14419283 ... 0.08986456 0.09131584 0.09795243] as keywo
rd args. From version 0.10 passing these as positional arguments will result in an error
  melspect = librosa.feature.melspectrogram(track_piece)
```

In [12]:
```
print(len(all_tracks))
```

```
7415
```

In [13]:
```
print(len(deceptive))
```

```
7415
```

In [53]:
```
#splitting into training and test sets
import numpy as np
from sklearn.model_selection import train_test_split
X_train, X_test, y_train, y_test = train_test_split(np.array(all_tracks),
                                                    np.array(deceptive),
                                                    test_size=0.2,
                                                    random_state=42)
X_train, X_val, y_train, y_val = train_test_split(X_train,
                                                    y_train,
                                                    test_size=0.1,
                                                    random_state=42)
```

In [54]:
```
X_train.shape
```

Out[54]:
```
(5338, 128, 20)
```

In [55]:
```
X_val.shape
```

Out[55]:
```
(594, 128, 20)
```

In [56]:
```
X_test.shape
```

Out[56]:
```
(1483, 128, 20)
```

In [62]:
```
#Creating cnn model
import tensorflow as tf
from tensorflow.keras import datasets, layers, models
import matplotlib.pyplot as plt

#Creating sequential model
model = models.Sequential()
#first layer is a relu convolutional 2d layer with 3x3 kernel
model.add(layers.Conv2D(64, (3, 3), activation='relu', input_shape=(128, 20, 1), padding='SAME'))
#second layer is a max pooling layer with 2x2 kernel
model.add(layers.MaxPooling2D((2, 2)))
model.add(layers.Dropout(0.2))
#third layer is a relu conv 2d layer with 3x3 kernel
model.add(layers.Conv2D(64, (3, 3), activation='relu', padding='SAME'))
model.add(layers.MaxPooling2D((2, 2)))
#fourth layer is max pooling layer with 2x2 kernel
model.add(layers.Dropout(0.2))
#fifth layer is relu conv 2d layer with 3x3 kernel
model.add(layers.Conv2D(64, (3, 3), activation='relu', padding='SAME'))
model.add(layers.Flatten())
#we add a flattening layer that flattens the input to a single 1d vector
model.add(layers.Dense(128, activation='relu'))
#we supply this to a dense relu layer with 64 nodes
#output layer is a dense layer with 1 node
model.add(layers.Dense(1))

model.summary()
```

```
Model: "sequential_15"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d_50 (Conv2D)          (None, 128, 20, 64)       640

 max_pooling2d_23 (MaxPoolin  (None, 64, 10, 64)       0
 g2D)

 dropout_25 (Dropout)        (None, 64, 10, 64)        0

 conv2d_51 (Conv2D)          (None, 64, 10, 64)        36928

 max_pooling2d_24 (MaxPoolin  (None, 32, 5, 64)        0
 g2D)

 dropout_26 (Dropout)        (None, 32, 5, 64)         0

 conv2d_52 (Conv2D)          (None, 32, 5, 64)         36928

 flatten_10 (Flatten)        (None, 10240)             0

 dense_20 (Dense)            (None, 128)               1310848

 dense_21 (Dense)            (None, 1)                 129

=================================================================
Total params: 1,385,473
Trainable params: 1,385,473
Non-trainable params: 0
_________________________________________________________________
```

In [64]:

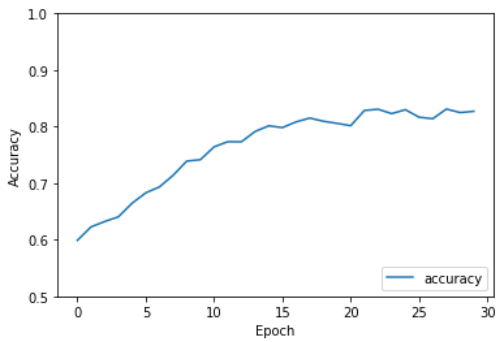
```
from tensorflow.keras.optimizers import RMSprop
#we compile the above model and fit it to the training data using binary cross entroy loss, rmsprop as the optimizer optimizing accuracy
model.compile(loss='binary_crossentropy',
              optimizer=RMSprop(learning_rate=0.001),
              metrics='accuracy')

history = model.fit(X_train, y_train, epochs=30)
```

```
Epoch 1/30
167/167 [==============================] - 21s 124ms/step - loss: 2.4985 - accuracy: 0.5989
Epoch 2/30
167/167 [==============================] - 20s 118ms/step - loss: 1.6789 - accuracy: 0.6227
Epoch 3/30
167/167 [==============================] - 20s 118ms/step - loss: 1.4090 - accuracy: 0.6323
Epoch 4/30
167/167 [==============================] - 19s 115ms/step - loss: 1.3739 - accuracy: 0.6405
Epoch 5/30
167/167 [==============================] - 18s 110ms/step - loss: 1.3793 - accuracy: 0.6645
Epoch 6/30
167/167 [==============================] - 19s 113ms/step - loss: 1.3858 - accuracy: 0.6828
Epoch 7/30
167/167 [==============================] - 18s 111ms/step - loss: 1.3301 - accuracy: 0.6933
Epoch 8/30
167/167 [==============================] - 20s 120ms/step - loss: 1.2491 - accuracy: 0.7138
Epoch 9/30
167/167 [==============================] - 19s 111ms/step - loss: 1.2048 - accuracy: 0.7390
Epoch 10/30
167/167 [==============================] - 20s 119ms/step - loss: 1.1755 - accuracy: 0.7415
Epoch 11/30
167/167 [==============================] - 21s 129ms/step - loss: 1.1516 - accuracy: 0.7641
Epoch 12/30
167/167 [==============================] - 21s 123ms/step - loss: 1.0049 - accuracy: 0.7733
Epoch 13/30
167/167 [==============================] - 20s 120ms/step - loss: 1.2333 - accuracy: 0.7731
Epoch 14/30
167/167 [==============================] - 20s 118ms/step - loss: 1.1702 - accuracy: 0.7913
Epoch 15/30
167/167 [==============================] - 20s 120ms/step - loss: 1.0101 - accuracy: 0.8014
Epoch 16/30
167/167 [==============================] - 22s 130ms/step - loss: 1.1243 - accuracy: 0.7982
Epoch 17/30
167/167 [==============================] - 23s 135ms/step - loss: 1.0468 - accuracy: 0.8084
Epoch 18/30
167/167 [==============================] - 19s 113ms/step - loss: 1.0097 - accuracy: 0.8151
Epoch 19/30
167/167 [==============================] - 19s 113ms/step - loss: 1.0649 - accuracy: 0.8095
Epoch 20/30
167/167 [==============================] - 18s 111ms/step - loss: 1.0314 - accuracy: 0.8057
Epoch 21/30
167/167 [==============================] - 19s 112ms/step - loss: 1.0312 - accuracy: 0.8016
Epoch 22/30
167/167 [==============================] - 20s 119ms/step - loss: 0.9190 - accuracy: 0.8286
Epoch 23/30
167/167 [==============================] - 19s 113ms/step - loss: 1.0041 - accuracy: 0.8306
Epoch 24/30
167/167 [==============================] - 19s 116ms/step - loss: 1.1264 - accuracy: 0.8230
Epoch 25/30
167/167 [==============================] - 19s 116ms/step - loss: 1.0399 - accuracy: 0.8299
Epoch 26/30
167/167 [==============================] - 19s 111ms/step - loss: 1.1507 - accuracy: 0.8166
Epoch 27/30
167/167 [==============================] - 19s 113ms/step - loss: 1.1694 - accuracy: 0.8140
Epoch 28/30
167/167 [==============================] - 21s 123ms/step - loss: 1.1579 - accuracy: 0.8310
Epoch 29/30
167/167 [==============================] - 19s 114ms/step - loss: 1.1632 - accuracy: 0.8248
Epoch 30/30
167/167 [==============================] - 19s 112ms/step - loss: 1.1924 - accuracy: 0.8271
```

In [65]:
```
import matplotlib.pyplot as plt
#we plot the accuracy to epoch number
plt.plot(history.history['accuracy'], label='accuracy')
plt.xlabel('Epoch')
plt.ylabel('Accuracy')
plt.ylim([0.5, 1])
plt.legend(loc='lower right')
```

Out[65]:
```
<matplotlib.legend.Legend at 0x1f3bea2cd30>
```



In [66]:
```
validation_loss, validation_acc = model.evaluate(X_val,  y_val, verbose=2)
```

```
19/19 - 0s - loss: 1.1902 - accuracy: 0.8013 - 380ms/epoch - 20ms/step
```

In [67]:
```
test_loss, test_acc = model.evaluate(X_test,  y_test, verbose=2)
```

```
47/47 - 1s - loss: 1.4085 - accuracy: 0.7849 - 754ms/epoch - 16ms/step
```

In [ ]:
```
#THANK YOU
```

6. Comparison, Results, and discussion along with Visualization

In this project, we have implemented one model for audio classification using CNN.

Summary of our model is given as

```
model.summary()
```

```
Model: "sequential_15"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d_50 (Conv2D)          (None, 128, 20, 64)       640

 max_pooling2d_23 (MaxPoolin  (None, 64, 10, 64)       0
 g2D)

 dropout_25 (Dropout)        (None, 64, 10, 64)        0

 conv2d_51 (Conv2D)          (None, 64, 10, 64)        36928

 max_pooling2d_24 (MaxPoolin  (None, 32, 5, 64)        0
 g2D)

 dropout_26 (Dropout)        (None, 32, 5, 64)         0

 conv2d_52 (Conv2D)          (None, 32, 5, 64)         36928

 flatten_10 (Flatten)        (None, 10240)             0

 dense_20 (Dense)            (None, 128)               1310848

 dense_21 (Dense)            (None, 1)                 129

=================================================================
Total params: 1,385,473
Trainable params: 1,385,473
Non-trainable params: 0
_________________________________________________________________
```

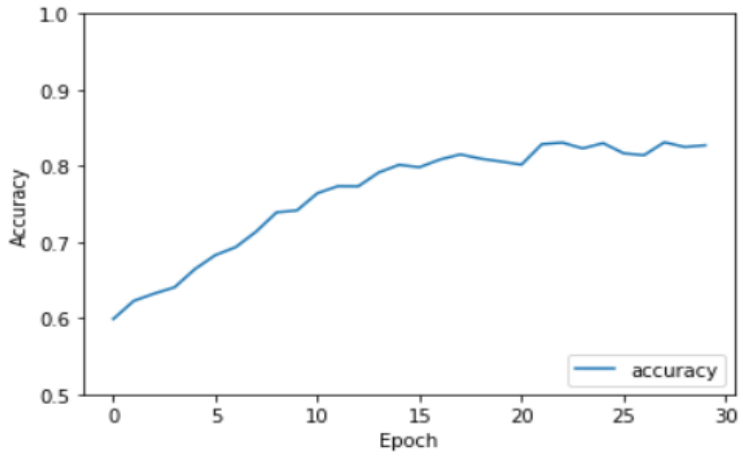
Our model has 3 convolution layers, 4 max-pooling layers, 2 dropout layers to prevent overfitting, a flatten layer to reduce the dimension and 2 dense layers which are the fully connected layers.

The total number of parameters are 1,385,473, all of which are trainable parameters.

```
167/167 [==============================] - 19s 112ms/step - loss: 1.0312 - accuracy: 0.8016
Epoch 22/30
167/167 [==============================] - 20s 119ms/step - loss: 0.9190 - accuracy: 0.8286
Epoch 23/30
167/167 [==============================] - 19s 113ms/step - loss: 1.0041 - accuracy: 0.8306
Epoch 24/30
167/167 [==============================] - 19s 116ms/step - loss: 1.1264 - accuracy: 0.8230
Epoch 25/30
167/167 [==============================] - 19s 116ms/step - loss: 1.0399 - accuracy: 0.8299
Epoch 26/30
167/167 [==============================] - 19s 111ms/step - loss: 1.1507 - accuracy: 0.8166
Epoch 27/30
167/167 [==============================] - 19s 113ms/step - loss: 1.1694 - accuracy: 0.8140
Epoch 28/30
167/167 [==============================] - 21s 123ms/step - loss: 1.1579 - accuracy: 0.8310
Epoch 29/30
167/167 [==============================] - 19s 114ms/step - loss: 1.1632 - accuracy: 0.8248
Epoch 30/30
167/167 [==============================] - 19s 112ms/step - loss: 1.1924 - accuracy: 0.8271
```

We ran 30 epochs on the model.

```
Out[65]: <matplotlib.legend.Legend at 0x1f3bea2cd30>
```




```
In [66]: validation_loss, validation_acc = model.evaluate(X_val,  y_val, verbose=2)
         19/19 - 0s - loss: 1.1902 - accuracy: 0.8013 - 380ms/epoch - 20ms/step

In [67]: test_loss, test_acc = model.evaluate(X_test,  y_test, verbose=2)
         47/47 - 1s - loss: 1.4085 - accuracy: 0.7849 - 754ms/epoch - 16ms/step
```

We can infer that the accuracy of the model gradually increases increase. Moreover, it took **20s for each epoch** to complete which is faster when compared to other more complex architectures.

Validation split contains 10% data. Validation accuracy is 80%.

Our test split contains 20% data. Test accuracy is 78%.

In the base research paper we referred, machine learning algorithms were used and achieved an accuracy of only 62%.

7. References - IEEE / APA std.

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