1. Importing Dependencies

```
import os
import cv2
import tensorflow as tf
import numpy as np
from typing import List
from matplotlib import pyplot as plt
import imageio
```

```
tf.config.list_physical_devices('GPU')
physical_devices = tf.config.list_physical_devices('GPU')
try:
    tf.config.experimental.set_memory_growth(physical_devices[0], True)
except:
    pass
```

2. Build Data Loading Functions

```
import gdown
url = 'https://drive.google.com/uc?id=1YlvpDLix3S-U8fd-gqRwPcWXAXm8JwjL'
output = 'data.zip'
gdown.download(url, output, quiet=False)
gdown.extractall('data.zip')
```

```
        'data/alignments/s1/swbpzp.align',
        'data/alignments/s1/swbv2n.align',
        'data/alignments/s1/swbv3s.align',
        'data/alignments/s1/swbv4p.align',
        'data/alignments/s1/swbv5a.align',
        'data/alignments/s1/swib2n.align',
        'data/alignments/s1/swib3s.align',
        'data/alignments/s1/swib4p.align',
        'data/alignments/s1/swib5a.align',
        'data/alignments/s1/swih6n.align',
        'data/alignments/s1/swih7s.align',
        'data/alignments/s1/swih8p.align',
        'data/alignments/s1/swih9a.align',
        'data/alignments/s1/swio1s.align',
        'data/alignments/s1/swio2p.align',
        'data/alignments/s1/swio3a.align',
        'data/alignments/s1/swiozn.align',
        'data/alignments/s1/swiu4n.align',
        'data/alignments/s1/swiu5s.align',
        'data/alignments/s1/swiu6p.align',
        'data/alignments/s1/swiu7a.align',
        'data/alignments/s1/swwc4n.align',
        'data/alignments/s1/swwc5s.align',
        'data/alignments/s1/swwc6p.align',
        'data/alignments/s1/swwc7a.align',
        'data/alignments/s1/swwi8n.align',
        'data/alignments/s1/swwi9s.align',
        'data/alignments/s1/swwj1a.align',
        'data/alignments/s1/swwjzp.align',
        'data/alignments/s1/swwp2n.align',
        'data/alignments/s1/swwp3s.align',
        'data/alignments/s1/swwp4p.align',
        'data/alignments/s1/swwp5a.align',
        'data/alignments/s1/swwv6n.align',
        ...]
```

```
def load_video(path:str) -> List[float]:

    cap = cv2.VideoCapture(path)
    frames = []
    for _ in range(int(cap.get(cv2.CAP_PROP_FRAME_COUNT))):
        ret, frame = cap.read()
        frame = tf.image.rgb_to_grayscale(frame)
        frames.append(frame[190:236,80:220,:])
    cap.release()

    mean = tf.math.reduce_mean(frames)
    std = tf.math.reduce_std(tf.cast(frames, tf.float32))
    return tf.cast((frames - mean), tf.float32) / std


vocab = [x for x in "abcdefghijklmnopqrstuvwxyz'?!123456789 "]
```

```
char_to_num = tf.keras.layers.StringLookup(vocabulary=vocab, oov_token="")
num_to_char = tf.keras.layers.StringLookup(
    vocabulary=char_to_num.get_vocabulary(), oov_token="", invert=True
)

print(
    f"The vocabulary is: {char_to_num.get_vocabulary()} "
    f"(size ={char_to_num.vocabulary_size()})"
)
```

```
The vocabulary is: ['', 'a', 'b', 'c', 'd', 'e', 'f', 'g', 'h', 'i', 'j', 'k', 'l', 'm',
```

```
def load_alignments(path:str) -> List[str]:
    with open(path, 'r') as f:
        lines = f.readlines()
    tokens = []
    for line in lines:
        line = line.split()
        if line[2] != 'sil':
            tokens = [*tokens,' ',line[2]]
    return char_to_num(tf.reshape(tf.strings.unicode_split(tokens, input_encoding='UTF-8'),


def load_data(path: str):
    path = bytes.decode(path.numpy())
    print("Original path:", path)

    # Corrected file name extraction
    file_name = path.split('/')[-1].split('.')[0]  # For Unix-like paths
    # Alternative for Windows: file_name = path.split('\\')[-1].split('.')[0]


    # Video path
    video_path = os.path.join('data','s1',f'{file_name}.mpg')

    # Alignment path
    alignment_path = os.path.join('data','alignments','s1',f'{file_name}.align')


    frames = load_video(video_path)
    alignments = load_alignments(alignment_path)
    return frames, alignments


test_path = './data/s1/bbal6n.mpg'


tf.convert_to_tensor(test_path).numpy().decode('utf-8').split('\\')[-1].split('.')[0]
```

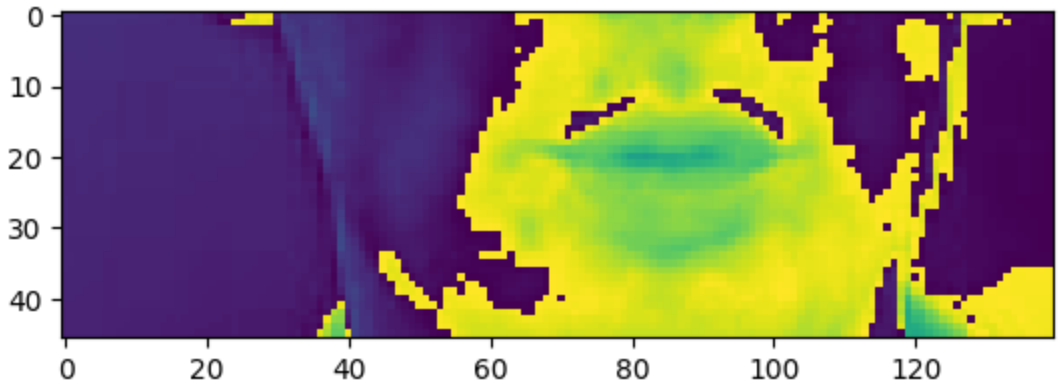
```
''
```

```
frames, alignments = load_data(tf.convert_to_tensor(test_path))
```

```
Original path: ./data/s1/bbal6n.mpg
Extracted file name: bbal6n
Video path: data/s1/bbal6n.mpg
Alignment path: data/alignments/s1/bbal6n.align
```

```
plt.imshow(frames[25])
```

```
<matplotlib.image.AxesImage at 0x7f907cf84670>
```




```
tf.strings.reduce_join([bytes.decode(x) for x in num_to_char(alignments.numpy()).numpy()])
```

```
<tf.Tensor: shape=(), dtype=string, numpy=b'bin blue at l six now'>
```

```
def mappable_function(path:str) ->List[str]:
    result = tf.py_function(load_data, [path], (tf.float32, tf.int64))
    return result
```

3. Creating Data Pipeline

```
from matplotlib import pyplot as plt
```

```
data = tf.data.Dataset.list_files('./data/s1/*.mpg')
data = data.shuffle(500, reshuffle_each_iteration=False)
data = data.map(mappable_function)
data = data.padded_batch(2, padded_shapes=([75,None,None,None],[40]))
data = data.prefetch(tf.data.AUTOTUNE)
# Added for split
train = data.take(450)
test = data.skip(450)
```

```
frames, alignments = data.as_numpy_iterator().next()
```

```
Original path: ./data/s1/bgbb1s.mpg
Extracted file name: bgbb1s
Video path: data/s1/bgbb1s.mpg
Alignment path: data/alignments/s1/bgbb1s.align
Original path: ./data/s1/swbo8n.mpg
Extracted file name: swbo8n
Video path: data/s1/swbo8n.mpg
Alignment path: data/alignments/s1/swbo8n.align
```

```
len(frames)
```

```
2
```

```
sample = data.as_numpy_iterator()
```

```
val = sample.next(); val[0]
```

```
         [ 0.11583739],
         [ 0.11583739]],

        [[ 1.3900486 ],
         [ 1.3900486 ],
         [ 1.3900486 ],
         ...,
         [ 0.15444985],
         [ 0.15444985],
         [ 0.11583739]],

        ...,

        [[ 1.003924  ],
         [ 1.0425365 ],
         [ 1.0425365 ],
         ...,
         [ 9.73034   ],
         [ 9.691728  ],
         [ 9.691728  ]],

        [[ 1.003924  ],
         [ 1.003924  ],
         [ 1.003924  ],
         ...,
```

```
imageio.mimsave('./animation.gif', val[0][0], fps=10)
```

```
WARNING:imageio:Lossy conversion from float32 to uint8. Range [0.0, 10.1276884078979
WARNING:imageio:Lossy conversion from float32 to uint8. Range [0.0, 10.1276884078979
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```

```
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WARNING:imageio:Lossy conversion from float32 to uint8. Range [0.0, 10.1276884078979!
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WARNING:imageio:Lossy conversion from float32 to uint8. Range [0.0, 10.1276884078979!
WARNING:imageio:Lossy conversion from float32 to uint8. Range [0.0, 10.1276884078979!
WARNING:imageio:Lossy conversion from float32 to uint8. Range [0.0, 10.1276884078979!
WARNING:imageio:Lossy conversion from float32 to uint8. Range [0.0, 10.1276884078979!
WARNING:imageio:Lossy conversion from float32 to uint8. Range [0.0, 10.1276884078979!
```
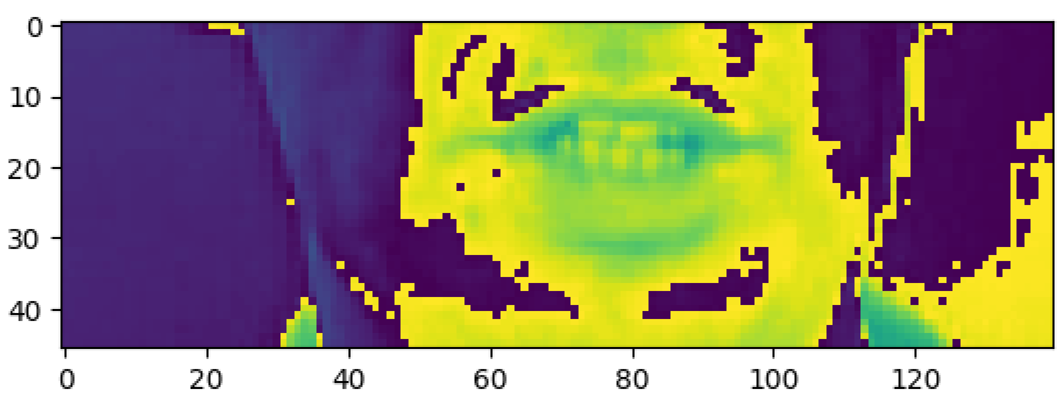

```
# 0:videos, 0: 1st video out of the batch,  0: return the first frame in the video
plt.imshow(val[0][0][35])
```

```
<matplotlib.image.AxesImage at 0x7f907c4ffa30>
```




```
tf.strings.reduce_join([num_to_char(word) for word in val[1][0]])
```

```
<tf.Tensor: shape=(), dtype=string, numpy=b'place white at j seven soon'>
```

4. Design the Deep Neural Network

```
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Conv3D, LSTM, Dense, Dropout, Bidirectional, MaxPool3D,
from tensorflow.keras.optimizers import Adam
from tensorflow.keras.callbacks import ModelCheckpoint, LearningRateScheduler
```

```
data.as_numpy_iterator().next()[0][0].shape
```

```
Original path: ./data/s1/pwwk5s.mpg
Extracted file name: pwwk5s
Video path: data/s1/pwwk5s.mpg
Alignment path: data/alignments/s1/pwwk5s.align
Original path: ./data/s1/sria7s.mpg
Extracted file name: sria7s
Video path: data/s1/sria7s.mpg
Alignment path: data/alignments/s1/sria7s.align
Original path: ./data/s1/bgwb7a.mpg
Extracted file name: bgwb7a
Video path: data/s1/bgwb7a.mpg
Alignment path: data/alignments/s1/bgwb7a.align
(75, 46, 140, 1)
```

```
model = Sequential()
model.add(Conv3D(128, 3, input_shape=(75,46,140,1), padding='same'))
model.add(Activation('relu'))
model.add(MaxPool3D((1,2,2)))

model.add(Conv3D(256, 3, padding='same'))
model.add(Activation('relu'))
model.add(MaxPool3D((1,2,2)))

model.add(Conv3D(75, 3, padding='same'))
model.add(Activation('relu'))
model.add(MaxPool3D((1,2,2)))

model.add(TimeDistributed(Flatten()))

model.add(Bidirectional(LSTM(128, kernel_initializer='Orthogonal', return_sequences=True)))
model.add(Dropout(.5))

model.add(Bidirectional(LSTM(128, kernel_initializer='Orthogonal', return_sequences=True)))
model.add(Dropout(.5))

model.add(Dense(char_to_num.vocabulary_size()+1, kernel_initializer='he_normal', activation=
```

```
model.summary()
```

```
Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv3d (Conv3D)             (None, 75, 46, 140, 128)  3584

 activation (Activation)     (None, 75, 46, 140, 128)  0

 max_pooling3d (MaxPooling3D  (None, 75, 23, 70, 128)  0
 )

 conv3d_1 (Conv3D)           (None, 75, 23, 70, 256)   884992

 activation_1 (Activation)   (None, 75, 23, 70, 256)   0

 max_pooling3d_1 (MaxPooling  (None, 75, 11, 35, 256)  0
 3D)

 conv3d_2 (Conv3D)           (None, 75, 11, 35, 75)    518475

 activation_2 (Activation)   (None, 75, 11, 35, 75)    0

 max_pooling3d_2 (MaxPooling  (None, 75, 5, 17, 75)    0
 3D)

 time_distributed (TimeDistr  (None, 75, 6375)         0
 ibuted)

 bidirectional (Bidirectiona  (None, 75, 256)          6660096
 l)

 dropout (Dropout)           (None, 75, 256)           0

 bidirectional_1 (Bidirectio  (None, 75, 256)          394240
 nal)

 dropout_1 (Dropout)         (None, 75, 256)           0

 dense (Dense)               (None, 75, 41)            10537

=================================================================
Total params: 8,471,924
Trainable params: 8,471,924
Non-trainable params: 0
_________________________________________________________________
```

```
yhat = model.predict(val[0])
```

```
1/1 [==============================] - 18s 18s/step
```

```
tf.strings.reduce_join([num_to_char(x) for x in tf.argmax(yhat[0],axis=1)])
```

```
<tf.Tensor: shape=(), dtype=string,
numpy=b'dddaaaaaaaaaaaaaaaaaaaaaaxxxxxxxxxxaaaaggggggggggggaaaggxxxxxxxxxxbbbbbb'>
```

```
tf.strings.reduce_join([num_to_char(tf.argmax(x)) for x in yhat[0]])
```

```
<tf.Tensor: shape=(), dtype=string,
numpy=b'dddaaaaaaaaaaaaaaaaaaaaaaaxxxxxxxxxxxaaaaggggggggggggaaaggxxxxxxxxxxxbbbbbb'>
```

```
model.input_shape
```

```
(None, 75, 46, 140, 1)
```

```
model.output_shape
```

```
(None, 75, 41)
```

5. Setup Training Options and Train

```
def scheduler(epoch, lr):
    if epoch < 30:
        return lr
    else:
        return lr * tf.math.exp(-0.1)
```

```
def CTCLoss(y_true, y_pred):
    batch_len = tf.cast(tf.shape(y_true)[0], dtype="int64")
    input_length = tf.cast(tf.shape(y_pred)[1], dtype="int64")
    label_length = tf.cast(tf.shape(y_true)[1], dtype="int64")

    input_length = input_length * tf.ones(shape=(batch_len, 1), dtype="int64")
    label_length = label_length * tf.ones(shape=(batch_len, 1), dtype="int64")

    loss = tf.keras.backend.ctc_batch_cost(y_true, y_pred, input_length, label_length)
    return loss
```

```
class ProduceExample(tf.keras.callbacks.Callback):
    def __init__(self, dataset) -> None:
        self.dataset = dataset.as_numpy_iterator()

    def on_epoch_end(self, epoch, logs=None) -> None:
        data = self.dataset.next()
        yhat = self.model.predict(data[0])
        decoded = tf.keras.backend.ctc_decode(yhat, [75,75], greedy=False)[0][0].numpy()
        for x in range(len(yhat)):
            print('Original:', tf.strings.reduce_join(num_to_char(data[1][x])).numpy().decoc
            print('Prediction:', tf.strings.reduce_join(num_to_char(decoded[x])).numpy().dec
            print('~'*100)
```

```
model.compile(optimizer=Adam(learning_rate=0.0001), loss=CTCLoss)
```

```
checkpoint_callback = ModelCheckpoint(os.path.join('models','checkpoint'), monitor='loss', s
```

```
schedule_callback = LearningRateScheduler(scheduler)
```

```
example_callback = ProduceExample(test)
```

```
# model.fit(train, validation_data=test, epochs=100, callbacks=[checkpoint_callback, schedul
```

6. Make a Prediction

```
url = 'https://drive.google.com/uc?id=1vWscXs4Vt0a_1IH1-ct2TCgXAZT-N3_Y'
output = 'checkpoints.zip'
gdown.download(url, output, quiet=False)
gdown.extractall('checkpoints.zip', 'models')
```

```
Downloading...
From (original): https://drive.google.com/uc?id=1vWscXs4Vt0a_1IH1-ct2TCgXAZT-N3_Y
From (redirected): https://drive.google.com/uc?id=1vWscXs4Vt0a_1IH1-ct2TCgXAZT-N3_Y&conf
To: /content/checkpoints.zip
100%|██████████| 94.5M/94.5M [00:01<00:00, 52.2MB/s]
['models/checkpoint.index',
 'models/__MACOSX/._checkpoint.index',
 'models/checkpoint.data-00000-of-00001',
 'models/__MACOSX/._checkpoint.data-00000-of-00001',
 'models/checkpoint',
 'models/__MACOSX/._checkpoint']
```

```
model.load_weights('models/checkpoint')
```

```
<tensorflow.python.checkpoint.checkpoint.CheckpointLoadStatus at 0x7f9074233f10>
```

```
test_data = test.as_numpy_iterator()
```

```
sample = test_data.next()
```

```
Original path: ./data/s1/bgbn9s.mpg
Extracted file name: bgbn9s
Video path: data/s1/bgbn9s.mpg
Alignment path: data/alignments/s1/bgbn9s.align
```

```
yhat = model.predict(sample[0])
```

```
1/1 [==============================] - 17s 17s/step
```

```
print('~'*100, 'REAL TEXT')
[tf.strings.reduce_join([num_to_char(word) for word in sentence]) for sentence in sample[1]]
```

```
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
[<tf.Tensor: shape=(), dtype=string, numpy=b'lay blue by y two now'>,
 <tf.Tensor: shape=(), dtype=string, numpy=b'set red with b eight now'>]
```

```
decoded = tf.keras.backend.ctc_decode(yhat, input_length=[75,75], greedy=True)[0][0].numpy()
```

```
print('~'*100, 'PREDICTIONS')
[tf.strings.reduce_join([num_to_char(word) for word in sentence]) for sentence in decoded]
```

```
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
[<tf.Tensor: shape=(), dtype=string, numpy=b'lay blue by y two now'>,
 <tf.Tensor: shape=(), dtype=string, numpy=b'set red with b eight now'>]
```

Test on a Video

```
sample = load_data(tf.convert_to_tensor('./data/s1/bras9a.mpg'))
```

```
Original path: ./data/s1/bras9a.mpg
Extracted file name: bras9a
Video path: data/s1/bras9a.mpg
Alignment path: data/alignments/s1/bras9a.align
```

```
print('~'*100, 'REAL TEXT')
[tf.strings.reduce_join([num_to_char(word) for word in sentence]) for sentence in [sample[1]]
```

```
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
[<tf.Tensor: shape=(), dtype=string, numpy=b'bin red at s nine again'>]
```

```
yhat = model.predict(tf.expand_dims(sample[0], axis=0))
```

```
1/1 [==============================] - 5s 5s/step
```

```
decoded = tf.keras.backend.ctc_decode(yhat, input_length=[75], greedy=True)[0][0].numpy()
```

```
print('~'*100, 'PREDICTIONS')
[tf.strings.reduce_join([num_to_char(word) for word in sentence]) for sentence in decoded]
```

```
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
[<tf.Tensor: shape=(), dtype=string, numpy=b'bin red at s nine again'>]
```