Repository Codes

Repository: ai_semantic_search

File: README.md

```
# BrainQuery - AI Semantic Search
Do you have difficulty finding relevant research papers? BrainQuery to the rescue! It employs AI Semantic Search to find hidden meaning behind searches and uses that to search through the abstracts of papers from the arXiv database - a large open-access archive of scientific material. (and yes, it has dark mode too!)

It even includes multi language support using OpenAI translation, which makes searches possible in any language.
## Technologies Used:

### Frontend:
- ReactJS
- Tailwind CSS

### Backend:
- Flask API
- OpenAI API (for Text Embeddings and Translation)
- Pinecone (Vector Database)

## Screenshots:
![Dark page](/images/dark.jpg?raw=true "Dark Page")

### Example Query: "minimum resource quantum computation increase"
![Query1](/images/query1.png?raw=true "Query1")

### Example Query (German): "I-V-Eigenschaften von MgB2" (translation: I-V properties of MgB2)
![Query2](/images/query2.png?raw=true "Query2")

### Example Query (Bengali): "??? ??????? ?????????? ?????????? ??????" (translation: min resource quantum computation increase)
![Query3](/images/query3.png?raw=true "Query3")

## How It Works:
The dataset consists of the arXiv Dataset (https://www.kaggle.com/datasets/Cornell-University/arxiv), of which, the first 15000 entries have been used for this project (due to Pinecone Restrictions). The embeddings for the abstract of each article were created (using OpenAI's ada-002 model), which has a dimensionality of 1536. These embeddings were then indexed in the Pincone Vector Database.
For Queries, this project uses OpenAI's translation (text completion via text-davinci-003 model) and embeddings (ada-002 model) to first translate given query into English and then embed it. A query is then made to the Pinecone database, which computes the top 5 items with consine similarity and returns the results as per ranking (most similar first), which is then displayed using the React frontend.
```

File: app.py

```
from dotenv import load_dotenv
from flask import Flask, request
import os
import openai
import pinecone
import json

app = Flask(__name__)

final = {}

# Loading environment variables
load_dotenv()
OPENAI_KEY = os.getenv("OPENAI_KEY")
PINECONE_KEY = os.getenv("PINECONE_KEY")

openai.api_key = OPENAI_KEY

# Selecting ada-002 model for text embeddings
MODEL = "text-embedding-ada-002"

# Initialize pinecone connection
pinecone.init(
api_key=PINECONE_KEY,
environment="us-west1-gcp"  # find next to api key in   console
)

# Select index name and connect to index
index_name = 'semantic-search'
index = pinecone.Index(index_name)


@app.route('/predictor', methods=["POST"])
def predict():
query = request.get_json()
# Translation API call
response = openai.Completion.create(
model="text-davinci-003",
prompt="Translate this to English (if already in english, just return input text): " +
query,
temperature=0.3,
max_tokens=15,
top_p=1.0,
frequency_penalty=0.0,
presence_penalty=0.0
)

# Created embeddings for translated text

xq            =            openai.Embedding.create(input=response['choices'][0]['text'],
engine=MODEL)['data'][0]['embedding']
res = index.query([xq], top_k=5, include_metadata=True)
```

```
for i in range(len(res['matches'])):
final[i] = res['matches'][i]['id']

json_obj = json.dumps(final)

return json_obj
```

File: index.html

```
<!DOCTYPE html>
<html lang="en">
<head>
<meta charset="utf-8" />
<link rel="icon" href="%PUBLIC_URL%/favicon.ico" />
<meta name="viewport" content="width=device-width, initial-scale=1" />
<meta name="theme-color" content="#000000" />
<meta name="description" content="Web site created using create-react-app"/>
<link rel="apple-touch-icon" href="%PUBLIC_URL%/logo192.png" />
<link rel="manifest" href="%PUBLIC_URL%/manifest.json" />
<title>BrainQuery</title>
</head>
<body>
<div id="root"></div>
</body>
</html>
```

File: robots.txt

```
# https://www.robotstxt.org/robotstxt.html
User-agent: *
Disallow:
```

Repository: ClearSkies

File: README.md

```
# ClearSkies
## Clear Skies: Predicting and Preventing Air Pollution

Air Pollution has been a long standing problem - specially in some urban cities of India. ClearSkies is a web app which aims to serve as a hub for getting education info, news, and serve predictions about Air Quality using a machine learning model

## Technologies Used:

### Frontend:
- ReactJS
- CSS

### Backend: (Planned, for serving Predictions and News)
- Django API
- Integrating News API for serving News regarding Air Pollution

### Model Training:
- XGBoost

# Screenshots

### Home Page:
![Home page](/assets/home.png?raw=true "Home Page")

### Educational Page (In progress):
![Edu page](/assets/placeholder_edu.png?raw=true "Edu Page")

### News Page (In progress):
![News page](/assets/placeholder_news.png?raw=true "Home Page")


### Predictions Page (In progress):
![Predictions page](/assets/placeholder_form.png?raw=true "Home Page")
```

File: model.ipynb

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"2                    142.05               43.51                528.40  2019   \n",
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"  from pandas import MultiIndex, Int64Index\n",
"c:\\Users\\techi\\anaconda3\\envs\\ml\\lib\\site-packages\\xgboost\\data.py:250: FutureWarning: pandas.Int64Index is deprecated and will be removed from pandas in a future version. Use pandas.Index with the appropriate dtype instead.\n",
"  elif isinstance(data.columns, (pd.Int64Index, pd.RangeIndex)):\n"
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gray;flex-grow: 1;}#sk-container-id-1 div.sk-label:hover label.sk-toggleable__label {background-color: #d4ebff;}#sk-container-id-1 div.sk-serial::before {content: \"\";position: absolute;border-left: 1px solid gray;box-sizing: border-box;top: 0;bottom: 0;left: 50%;z-index: 0;}#sk-container-id-1 div.sk-serial {display: flex;flex-direction: column;align-items: center;background-color: white;padding-right: 0.2em;padding-left: 0.2em;position: relative;}#sk-container-id-1 div.sk-item {position: relative;z-index: 1;}#sk-container-id-1 div.sk-parallel {display: flex;align-items: stretch;justify-content: center;background-color: white;position: relative;}#sk-container-id-1 div.sk-item::before, #sk-container-id-1 div.sk-parallel-item::before {content: \"\";position: absolute;border-left: 1px solid gray;box-sizing: border-box;top: 0;bottom: 0;left: 50%;z-index: -1;}#sk-container-id-1 div.sk-parallel-item {display: flex;flex-direction: column;z-index: 1;position: relative;background-color: white;}#sk-container-id-1 div.sk-parallel-item:first-child::after {align-self: flex-end;width: 50%;}#sk-container-id-1 div.sk-parallel-item:last-child::after {align-self: flex-start;width: 50%;}#sk-container-id-1 div.sk-parallel-item:only-child::after {width: 0;}#sk-container-id-1 div.sk-dashed-wrapped {border: 1px dashed gray;margin: 0 0.4em 0.5em 0.4em;box-sizing: border-box;padding-bottom: 0.4em;background-color: white;}#sk-container-id-1 div.sk-label label {font-family: monospace;font-weight: bold;display: inline-block;line-height: 1.2em;}#sk-container-id-1 div.sk-label-container {text-align: center;}#sk-container-id-1 div.sk-container {/* jupyter's `normalize.less` sets `[hidden] { display: none; }` but bootstrap.min.css set `[hidden] { display: none !important; }` so we also need the `!important` here to be able to override the default hidden behavior on the sphinx rendered scikit-learn.org. See: https://github.com/scikit-learn/scikit-learn/issues/21755 */display: inline-block !important;position: relative;}#sk-container-id-1 div.sk-text-repr-fallback {display: none;}</style><div id=\"sk-container-id-1\" class=\"sk-top-container\"><div class=\"sk-text-repr-fallback\"><pre>XGBRegressor(base_score=0.5,
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max_delta_step=0,\n",
"max_depth=6, min_child_weight=1, missing=nan,\n",
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reg_alpha=0,\n",
"reg_lambda=1, scale_pos_weight=1, subsample=1,
tree_method='exact',\n",
"validate_parameters=1, verbosity=None)</pre>In a Jupyter environment, please rerun this cell to show the HTML representation or trust the notebook.
On GitHub, the HTML representation is unable to render, please try loading this page with nbviewer.org. <div class=\"sk-container\" hidden><div class=\"sk-item\"><div class=\"sk-estimator sk-toggleable\"><input class=\"sk-toggleable__control sk-hidden--visually\" id=\"sk-estimator-id-1\" type=\"checkbox\" checked><label for=\"sk-estimator-id-1\" class=\"sk-toggleable__label sk-toggleable__label-arrow\">XGBRegressor</label><div class=\"sk-toggleable__content\"><pre>XGBRegressor(base_score=0.5,
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"model.fit(X_train, y_train)\n"
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https://pandas.pydata.org/pandas-docs/stable/user_guide/indexing.html#returning-a-view-v
ersus-a-copy\n",
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```

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tree_method='exact',\n",
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please rerun this cell to show the HTML representation or trust the notebook.
On
GitHub, the HTML representation is unable to render, please try loading this page with
nbviewer.org. <div class=\"sk-container\" hidden><div class=\"sk-item\"><div
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Repository: dev-portfolio

File: README.md

```
Developer Portfolio
```

File: index.html

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<!DOCTYPE html>
<html>
<body>

<h1>Hello World!</h1>

</body>
</html>
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Repository: EEG_Classification

File: README.md

```
# EEG_Classification
EEG Classification (Mini Project)
```

File: eeg_BCI.ipynb

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"import scipy.io\n",
"%matplotlib inline"
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"# SciPy.io.loadmat does not deal well with Matlab structures, resulting in lots of\n",
"# extra dimensions in the arrays. This makes the code a bit more cluttered\n",
"\n",
"sample_rate = m['nfo']['fs'][0][0][0][0]\n",
"EEG = m['cnt'].T\n",
"nchannels, nsamples = EEG.shape\n",
"\n",
"channel_names = [s[0] for s in m['nfo']['clab'][0][0][0]]\n",
"event_onsets = m['mrk'][0][0][0]\n",
"event_codes = m['mrk'][0][0][1]\n",
"labels = np.zeros((1, nsamples), int)\n",
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'CP4', 'CP6', 'P5', 'P3', 'P1', 'Pz', 'P2', 'P4', 'P6', 'PO1', 'PO2', 'O1', 'O2']\n",
"Number of events: 1\n",
"Event codes: [-1  1]\n",
"Class labels: ['left', 'right']\n",
"Number of classes: 2\n"
]
}
],
"source": [
"# Print some information\n",
"print('Shape of EEG:', EEG.shape)\n",
"print('Sample rate:', sample_rate)\n",
"print('Number of channels:', nchannels)\n",
"print('Channel names:', channel_names)\n",
"print('Number of events:', len(event_onsets))\n",
"print('Event codes:', np.unique(event_codes))\n",
"print('Class labels:', cl_lab)\n",
"print('Number of classes:', nclasses)"
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"from matplotlib.collections import LineCollection\n",
"\n",
"def plot_eeg(EEG, vspace=200, color='k'):\n",
"    '''\n",
"    Plot the EEG data, stacking the channels horizontally on top of each other.\n",
"\n",
"    Parameters\n",
"    ----------\n",
"    EEG : array (channels x samples)\n",
"        The EEG data\n",
"    vspace : float (default 100)\n",
"        Amount of vertical space to put between the channels\n",
"    color : string (default 'k')\n",
"        Color to draw the EEG in\n",
"    '''\n",
"    \n",
"    bases = vspace * np.arange(59)\n",
"    \n",
"    EEG = EEG.T + bases\n",
"    \n",
"    # Calculate a timeline in seconds, knowing that the sample rate of the EEG recorder
was 100 Hz.\n",
"    samplerate = 100.\n",
"    time = np.arange(EEG.shape[0]) / samplerate\n",
"    \n",
"    # Plot EEG versus time\n",
"    plt.plot(time, EEG, color=color)\n",
"\n",
"    # Add gridlines to the plot\n",
"    plt.grid()\n",
"    \n",
"    # Label the axes\n",
"    plt.xlabel('Time (s)')\n",
"    plt.ylabel('Channels')\n",
"    \n",
"     # The y-ticks are set to the locations of the electrodes. The international 10-20
system defines\n",
"    # default names for them.\n",
"    plt.gca().yaxis.set_ticks(bases)\n",
"    plt.gca().yaxis.set_ticklabels(channel_names)\n",
"    \n",
"    # Put a nice title on top of the plot\n",
```

```
"    plt.title('EEG data')\n",
"\n",
"\n",
"# Testing our function\n",
"plt.figure(figsize=(250, 120))\n",
"# plot_eeg(EEG, 3000)"
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"non_zero_i"
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"for i in range(1, len(non_zero_i)):\n",
"    if non_zero_i[i - 1] != non_zero_i[i] - 1:\n",
"        onsets.append(non_zero_i[i])\n",
"onsets = np.asarray(onsets)\n",
"onsets"
]
},
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```
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"# plt.figure(figsize=(300, 100))\n",
"# plot_eeg(EEG, 1000)\n",
"# for onset in onsets:\n",
"#     plt.axvline(onset / 100., color='r')\n"
]
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"First 10 trials are:\n"
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" (2945, 3145),\n",
" (3745, 3945),\n",
" (4545, 4745),\n",
" (5345, 5545),\n",
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" (9345, 9545)]"
]
},
"execution_count": 9,
"metadata": {},
"output_type": "execute_result"
}
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"source": [
"# Creating time slices with a window of 0.85 secs\n",
"time_slices = [(int(s + 0.5*100), int(s + 2.5 * 100)) for s in onsets]\n",
"print(\"Length of time_slices:\", len(time_slices))\n",
"print(\"First 10 trials are:\")\n",
"time_slices[:10] # Showing 10 trial onsets and ending times"
]
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```

```
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"trials = [EEG[:, s:e] for s, e in time_slices]\n",
"trials = np.asarray(trials)\n",
"print(\"Shape of trials:\", trials.shape)"
]
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"(59, 200, 200)"
]
},
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"metadata": {},
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}
],
"source": [
"trials = np.transpose(trials, (1, 2, 0))\n",
"trials.shape\n",
"# Now trials is in (channels x time x no. of trials) form"
]
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}
],
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"non_zero_labels = [int(labels[:, onset]) for onset in onsets]\n",
"print(\"Number of trials:\", len(non_zero_labels))"
]
},
```

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"output_type": "stream",
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"Shape of trials_2: (59, 200, 100)\n"
]
}
],
"source": [
"trialscl1 = []\n",
"trialscl2 = []\n",
"for i in range(len(non_zero_labels)):\n",
"   if int(non_zero_labels[i]) == 1:\n",
"   trialscl1.append(trials[:, :, i])\n",
"   elif int(non_zero_labels[i]) == -1:\n",
"   trialscl2.append(trials[:, :, i])\n",
"\n",
"trialscl1 = np.asarray(trialscl1)\n",
"trialscl2 = np.asarray(trialscl2)\n",
"trialscl1 = np.transpose(trialscl1, (1, 2, 0))\n",
"trialscl2 = np.transpose(trialscl2, (1, 2, 0))\n",
"\n",
"print(\"Shape of trials_1:\", trialscl1.shape)\n",
"print(\"Shape of trials_2:\", trialscl2.shape)"
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"def psd(trials):\n",

```
"    '''\n",
"    Calculates for each trial the Power Spectral Density (PSD).\n",
"    \n",
"    Parameters\n",
"    ----------\n",
"    trials : 3d-array (channels x samples x trials)\n",
"        The EEG signal\n",
"    \n",
"    Returns\n",
"    -------\n",
"    trial_PSD : 3d-array (channels x PSD x trials)\n",
"        the PSD for each trial.  \n",
"    freqs : list of floats\n",
"        Yhe frequencies for which the PSD was computed (useful for plotting later)\n",
"    '''\n",
"    \n",
"    ntrials = trials.shape[2]\n",
"    trials_PSD = np.zeros((nchannels, 101, ntrials))\n",
"\n",
"    # Iterate over trials and channels\n",
"    for trial in range(ntrials):\n",
"        for ch in range(nchannels):\n",
"            # Calculate the PSD\n",
"                        (PSD,  freqs)  =  mlab.psd(trials[ch,:,trial],  NFFT=int(200),
Fs=sample_rate)\n",
"            trials_PSD[ch, :, trial] = PSD.ravel()\n",
"                \n",
"    return trials_PSD, freqs"
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"psd_f, freqs = psd(trialscl2)\n",
"trials_PSD = {1: psd_r, 2: psd_f}"
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"import matplotlib.pyplot as plt\n",
"\n",
"def plot_psd(trials_PSD, freqs, chan_ind, chan_lab=None, maxy=None):\n",
"    '''\n",
"    Plots PSD data calculated with psd().\n",
"    \n",
```

```
"    Parameters\n",
"    ----------\n",
"    trials : 3d-array\n",
"        The PSD data, as returned by psd()\n",
"    freqs : list of floats\n",
"        The frequencies for which the PSD is defined, as returned by psd() \n",
"    chan_ind : list of integers\n",
"        The indices of the channels to plot\n",
"    chan_lab : list of strings\n",
"        (optional) List of names for each channel\n",
"    maxy : float\n",
"        (optional) Limit the y-axis to this value\n",
"    '''\n",
"    plt.figure(figsize=(12,5))\n",
"    \n",
"    nchans = len(chan_ind)\n",
"    \n",
"    # Maximum of 3 plots per row\n",
"    nrows = int(np.ceil(nchans / 3))\n",
"    ncols = min(3, nchans)\n",
"    \n",
"    # Enumerate over the channels\n",
"    for i,ch in enumerate(chan_ind):\n",
"        # Figure out which subplot to draw to\n",
"        plt.subplot(nrows,ncols,i+1)\n",
"    \n",
"        # Plot the PSD for each class\n",
"        for cl in trials_PSD.keys():\n",
"            plt.plot(freqs, np.mean(trials_PSD[cl][ch,:,:], axis=1), label=cl)\n",
"    \n",
"        # All plot decoration below...\n",
"        \n",
"        plt.xlim(1,30)\n",
"        \n",
"        if maxy != None:\n",
"            plt.ylim(0,maxy)\n",
"    \n",
"        plt.grid()\n",
"    \n",
"        plt.xlabel('Frequency (Hz)')\n",
"        \n",
"        if chan_lab == None:\n",
"            plt.title('Channel %d' % (ch+1))\n",
"        else:\n",
"            plt.title(chan_lab[i])\n",
"\n",
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"    Designs and applies a bandpass filter to the signal.\n",
"    \n",
"    Parameters\n",
"    ----------\n",
"    trials : 3d-array (channels x samples x trials)\n",
"        The EEGsignal\n",
"    lo : float\n",
"        Lower frequency bound (in Hz)\n",
"    hi : float\n",
"        Upper frequency bound (in Hz)\n",
"    sample_rate : float\n",
"        Sample rate of the signal (in Hz)\n",
"    \n",
"    Returns\n",
```

"   -------\n",
"   trials_filt : 3d-array (channels x samples x trials)\n",
"   The bandpassed signal\n",
"   '''\n",
"\n",
"   # The iirfilter() function takes the filter order: higher numbers mean a sharper frequency cutoff,\n",
"   # but the resulting signal might be shifted in time, lower numbers mean a soft frequency cutoff,\n",
"   # but the resulting signal less distorted in time. It also takes the lower and upper frequency bounds\n",
"   # to pass, divided by the niquist frequency, which is the sample rate divided by 2:\n",
"   a, b = scipy.signal.iirfilter(6, [lo/(sample_rate/2.0), hi/(sample_rate/2.0)])\n",
"\n",
"   # Applying the filter to each trial\n",
"   ntrials = trials.shape[2]\n",
"   trials_filt = np.zeros((nchannels, 200, ntrials))\n",
"   for i in range(ntrials):\n",
"   trials_filt[:,:,i] = scipy.signal.filtfilt(a, b, trials[:,:,i], axis=1)\n",
"   \n",
"   return trials_filt"
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"def logvar(trials):\n",
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"   Calculate the log-var of each channel.\n",
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"   Parameters\n",
"   ----------\n",
"   trials : 3d-array (channels x samples x trials)\n",
"   The EEG signal.\n",
"   \n",
"   Returns\n",
"   -------\n",
"   logvar - 2d-array (channels x trials)\n",

```
"        For each channel the logvar of the signal\n",
"    '''\n",
"    return np.log(np.var(trials, axis=1))"
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"def plot_logvar(trials):\n",
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"    Plots the log-var of each channel/component.\n",
"    arguments:\n",
"              trials  -  Dictionary  containing  the  trials  (log-vars  x  trials)  for  2
classes.\n",
"    '''\n",
"    plt.figure(figsize=(12,5))\n",
"    \n",
"    x0 = np.arange(nchannels)\n",
"    x1 = np.arange(nchannels) + 0.4\n",
"\n",
"    y0 = np.mean(trials[1], axis=1)\n",
"    y1 = np.mean(trials[2], axis=1)\n",
"\n",
"    plt.bar(x0, y0, width=0.5, color='b')\n",
"    plt.bar(x1, y1, width=0.4, color='r')\n",
"\n",
"    plt.xlim(-0.5, nchannels+0.5)\n",
"\n",
"    plt.gca().yaxis.grid(True)\n",
"    plt.title('log-var of each channel/component')\n",
"    plt.xlabel('channels/components')\n",
"    plt.ylabel('log-var')\n",
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"   ntrials = trials.shape[2]\n",
"   covs = [trials[:,:,i].dot(trials[:,:,i].T) / 200 for i in range(ntrials)]\n",
"   return np.mean(covs, axis=0)\n",
"\n",
"def whitening(sigma):\n",
"   ''' Calculate a whitening matrix for covariance matrix sigma. '''\n",
"   U, l, _ = linalg.svd(sigma)\n",
"   return U.dot(np.diag(l ** -0.5))\n",
"\n",
"def csp(trials_r, trials_f):\n",
"   '''\n",
"   Calculate the CSP transformation matrix W.\n",

```
"    arguments:\n",
"         trials_r - Array (channels x samples x trials) containing right hand movement trials\n",
"            trials_f - Array (channels x samples x trials) containing foot movement trials\n",
"    returns:\n",
"        Mixing matrix W\n",
"    '''\n",
"    cov_r = cov(trials_r)\n",
"    cov_f = cov(trials_f)\n",
"    P = whitening(cov_r + cov_f)\n",
"    B, _, _ = linalg.svd( P.T.dot(cov_f).dot(P) )\n",
"    W = P.dot(B)\n",
"    return W\n",
"\n",
"def apply_mix(W, trials):\n",
"     ''' Apply a mixing matrix to each trial (basically multiply W with the EEG signal matrix)'''\n",
"    ntrials = trials.shape[2]\n",
"    trials_csp = np.zeros((nchannels, 200, ntrials))\n",
"    for i in range(ntrials):\n",
"        trials_csp[:,:,i] = W.T.dot(trials[:,:,i])\n",
"    return trials_csp"
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"ntrain_f = int(trials_filt[2].shape[2] * train_percentage)\n",
"ntest_r = trials_filt[1].shape[2] - ntrain_r\n",
"ntest_f = trials_filt[2].shape[2] - ntrain_f\n",
"\n",
"# Splitting the frequency filtered signal into a train and test set\n",
"train = {1: trials_filt[1][:,:,:ntrain_r],\n",
"         2: trials_filt[2][:,:,:ntrain_f]}\n",
"\n",
"test = {1: trials_filt[1][:,:,ntrain_r:],\n",
"        2: trials_filt[2][:,:,ntrain_f:]}\n",
"\n",
"# Train the CSP on the training set only\n",
"W = csp(train[1], train[2])\n",
"\n",
"# Apply the CSP on both the training and test set\n",
"train[1] = apply_mix(W, train[1])\n",
"train[2] = apply_mix(W, train[2])\n",
"test[1] = apply_mix(W, test[1])\n",
"test[2] = apply_mix(W, test[2])\n",
"\n",
"# Select only the first and last components for classification\n",
"comp = np.array([0,-1])\n",
"train[1] = train[1][comp,:,:]\n",
"train[2] = train[2][comp,:,:]\n",
"test[1] = test[1][comp,:,:]\n",
"test[2] = test[2][comp,:,:]\n",
"\n",
"# Calculate the log-var\n",
"train[1] = logvar(train[1])\n",
"train[2] = logvar(train[2])\n",
```

```
"test[1] = logvar(test[1])\n",
"test[2] = logvar(test[2])"
]
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"def train_lda(class1, class2):\n",
"    '''\n",
"    Trains the LDA algorithm.\n",
"    arguments:\n",
"        class1 - An array (observations x features) for class 1\n",
"        class2 - An array (observations x features) for class 2\n",
"    returns:\n",
"        The projection matrix W\n",
"        The offset b\n",
"    '''\n",
"    nclasses = 2\n",
"    \n",
"    nclass1 = class1.shape[0]\n",
"    nclass2 = class2.shape[0]\n",
"    \n",
"    # Class priors: in this case, we have an equal number of training\n",
"    # examples for each class, so both priors are 0.5\n",
"    prior1 = nclass1 / float(nclass1 + nclass2)\n",
"    prior2 = nclass2 / float(nclass1 + nclass1)\n",
"   \n",
"    mean1 = np.mean(class1, axis=0)\n",
"    mean2 = np.mean(class2, axis=0)\n",
"    \n",
"    class1_centered = class1 - mean1\n",
"    class2_centered = class2 - mean2\n",
"    \n",
"    # Calculate the covariance between the features\n",
"    cov1 = class1_centered.T.dot(class1_centered) / (nclass1 - nclasses)\n",
"    cov2 = class2_centered.T.dot(class2_centered) / (nclass2 - nclasses)\n",
"   \n",
"    W = (mean2 - mean1).dot(np.linalg.pinv(prior1*cov1 + prior2*cov2))\n",
"    b = (prior1*mean1 + prior2*mean2).dot(W)\n",
"    \n",
"    return (W,b)\n",
"\n",
"def apply_lda(test, W, b):\n",
"    '''\n",
"    Applies a previously trained LDA to new data.\n",
"    arguments:\n",
"        test - An array (features x trials) containing the data\n",
"        W    - The project matrix W as calculated by train_lda()\n",
"        b    - The offsets b as calculated by train_lda()\n",
"    returns:\n",
"        A list containing a classlabel for each trial\n",
```

```
"    '''\n",
"    ntrials = test.shape[1]\n",
"    \n",
"    prediction = []\n",
"    for i in range(ntrials):\n",
"        # The line below is a generalization for:\n",
"        # result = W[0] * test[0,i] + W[1] * test[1,i] - b\n",
"        result = W.dot(test[:,i]) - b\n",
"        if result <= 0:\n",
"            prediction.append(1)\n",
"        else:\n",
"            prediction.append(2)\n",
"    \n",
"    return np.array(prediction)"
]
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"b: -0.38024720917511434\n"
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"W,b = train_lda(train[1].T, train[2].T)\n",
"\n",
"print('W:', W)\n",
"print('b:', b)"
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"labels = np.asarray(list_markers)\n",
"\n",
"sample_rate = m['o']['sampFreq'][0][0][0][0]\n",
"# Loading channel names\n",
"channel_names = [s[0][0] for s in m['o']['chnames'][0][0]]\n",
"nchannels, nsamples = EEG.shape\n",
"list_markers = [s[0] for s in m['o']['marker'][0][0]]\n",
"unique_events = np.unique(list_markers)\n",
"\n",
"print(\"EEG Dimensions: \", EEG.shape)\n",
"print(\"Label Dimensions: \", labels.shape)\n",
"print(\"Sample Rate:\", sample_rate)\n",
"print(\"Number of channels:\", nchannels)\n",
"print(\"Channel names:\", channel_names)\n",
"print(\"Event codes:\", unique_events)\n"
]
},
{
```

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"from matplotlib.collections import LineCollection\n",
"\n",
"def plot_eeg(EEG, vspace=200, color='k'):\n",
"    '''\n",
"    Plot the EEG data, stacking the channels horizontally on top of each other.\n",
"\n",
"    Parameters\n",
"    ----------\n",
"    EEG : array (channels x samples)\n",
"        The EEG data\n",
"    vspace : float (default 100)\n",
"        Amount of vertical space to put between the channels\n",
"    color : string (default 'k')\n",
"        Color to draw the EEG in\n",
"    '''\n",
"    \n",
"    bases = vspace * np.arange(22)\n",
"    \n",
"    EEG = EEG.T + bases\n",
"    \n",
"    # Calculate a timeline in seconds, knowing that the sample rate of the EEG recorder
was 200 Hz.\n",
"    samplerate = 200.\n",
"    time = np.arange(EEG.shape[0]) / samplerate\n",
"    \n",
"    # Plot EEG versus time\n",
"    plt.plot(time, EEG, color=color)\n",
"\n",
"    # Add gridlines to the plot\n",
"    plt.grid()\n",
"    \n",
"    # Label the axes\n",
"    plt.xlabel('Time (s)')\n",
"    plt.ylabel('Channels')\n",
"    \n",
"     # The y-ticks are set to the locations of the electrodes. The international 10-20
system defines\n",
"    # default names for them.\n",
"    plt.gca().yaxis.set_ticks(bases)\n",
"    plt.gca().yaxis.set_ticklabels(channel_names)\n",
"    \n",
"    # Put a nice title on top of the plot\n",
"    plt.title('EEG data')\n",
"\n",
"\n",
"# Testing our function\n",
"plt.figure(figsize=(25, 12))\n",
"plot_eeg(EEG, 300)"
]
```

```
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"labels.shape"
]
},
{
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"non_zero_i = np.flatnonzero(labels)\n",
"non_zero_i"
]
},
{
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"onsets = [non_zero_i[0]]\n",
"for i in range(1, len(non_zero_i)):\n",
"    if non_zero_i[i - 1] != non_zero_i[i] - 1:\n",
"        onsets.append(non_zero_i[i])\n",
"onsets = np.asarray(onsets)\n",
"onsets"
]
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"plt.figure(figsize=(300, 100))\n",
"plot_eeg(EEG, 400)\n",
"for onset in onsets:\n",
"    plt.axvline(onset / 200., color='r')\n"
]
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"# Creating time slices with a window of 1 sec\n",
"time_slices = [(s, int(s + 1* 200)) for s in onsets]\n",
```

```
"print(\"Length of time_slices:\", len(time_slices))\n",
"print(\"First 10 trials are:\")\n",
"time_slices[:10] # Showing 10 trial onsets and ending times"
]
},
{
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"trials = [EEG[:, s:e] for s, e in time_slices]\n",
"trials = np.asarray(trials)\n",
"print(\"Shape of trials:\", trials.shape)"
]
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"plot_eeg(trials[0], 20)\n",
"print(trials[0].shape)"
]
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{
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"from scipy.signal import stft\n",
"\n",
"def apply_stft(signal, sampling_rate, window_size=64, overlap=0.5):\n",
"    \"\"\"\n",
"    Apply Short-Time Fourier Transform (STFT) to a given signal.\n",
"\n",
"    Parameters\n",
"    ----------\n",
"    signal : array\n",
"        Input signal\n",
"    sampling_rate : int\n",
"        Sampling rate of the signal\n",
"    window_size : int (default: 64)\n",
"        Size of the STFT window\n",
"    overlap : float (default: 0.5)\n",
"        Overlap between consecutive STFT windows\n",
"\n",
"    Returns\n",
"    -------\n",
"    stft_output : array\n",
"        STFT output\n",
"    \"\"\"\n",
```

```
"    overlap = int(window_size * overlap)\n",
"            f,   t,   stft_output   =   stft(signal,   fs=sampling_rate,   window='hann',
nperseg=window_size, noverlap=overlap)\n",
"    return f, t, stft_output\n"
]
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{
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]
},
{
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"# Apply STFT to the first trial's C3 channel\n",
"f, t, stft_output = apply_stft(trials[0][4, :], sampling_rate=200, overlap=0.6)\n",
"\n",
"# Plot the spectrogram\n",
"plt.pcolormesh(t, f, np.abs(stft_output), cmap='plasma')\n",
"plt.ylabel('Frequency [Hz]')\n",
"plt.xlabel('Time [sec]')\n",
"plt.title('Spectrogram of the first trial\\'s C3 channel')\n"
]
},
{
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"for trial in trials:\n",
"    print(trial.shape)\n",
"    break"
]
},
{
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"source": [
"def avg_stft(trials, channels, sampling_rate, window_size=64, overlap=0.5):\n",
"    \"\"\"\n",
"    Compute the average STFT across selected channels for each trial.\n",
"\n",
"    Parameters\n",
"    ----------\n",
```

```
"    trials : array\n",
"        EEG data trials\n",
"    channels : list\n",
"        List of channel indices to compute the average STFT for\n",
"    sampling_rate : int\n",
"        Sampling rate of the EEG data\n",
"    window_size : int (default: 64)\n",
"        Size of the STFT window\n",
"    overlap : float (default: 0.5)\n",
"        Overlap between consecutive STFT windows\n",
"\n",
"    Returns\n",
"    -------\n",
"    f : array\n",
"        Array of frequencies\n",
"    t : array\n",
"        Array of time points\n",
"    avg_stft : array\n",
"        Array of averaged STFT values across selected channels\n",
"    \"\"\"\n",
"    stft_all = []\n",
"    for trial in trials:\n",
"        stft_trial = []\n",
"        for channel in channels:\n",
"                                f,   t,   stft_output   =   apply_stft(trial[channel,   :],
sampling_rate=sampling_rate, window_size=window_size, overlap=overlap)\n",
"            stft_trial.append(np.abs(stft_output))\n",
"        stft_trial = np.asarray(stft_trial)\n",
"        stft_avg = np.mean(stft_trial, axis=0)\n",
"        stft_all.append(stft_avg)\n",
"    stft_all = np.asarray(stft_all)\n",
"    # avg_stft = np.mean(stft_all, axis=0)\n",
"    return f, t, stft_all\n"
]
},
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"source": [
"channels = [3, 4, 5, 6, 18, 19]\n",
"f, t, stft_all = avg_stft(trials, channels, sampling_rate=200, overlap=0.6)\n",
"\n",
"plt.pcolormesh(t, f, abs(stft_all[0]), cmap='plasma')\n",
"plt.ylabel('Frequency [Hz]')\n",
"plt.xlabel('Time [sec]')\n",
"plt.title('Average spectrogram for selected channels')\n"
]
},
{
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```

```
"outputs": [],
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"trials[0][4, :].shape"
]
},
{
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"outputs": [],
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"for i in range(5):\n",
"    plt.pcolormesh(t, f, stft_all[i], cmap='plasma')\n",
"    plt.ylabel('Frequency [Hz]')\n",
"    plt.xlabel('Time [sec]')\n",
"    plt.title('Average spectrogram for selected channels')\n",
"    plt.show()\n"
]
},
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"source": [
"stft_all[0].shape"
]
},
{
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"non_zero_labels = [labels[onset] for onset in onsets]\n",
"print(\"Number of trials:\", len(non_zero_labels))"
]
},
{
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"source": [
"print(\"stft_all shape:\", stft_all.shape)\n",
"print(\"labels:\", len(non_zero_labels))"
]
},
{
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"outputs": [],
"source": [
```

```
"import os\n",
"import matplotlib.pyplot as plt\n",
"\n",
"# Create a dictionary to map labels to class directories\n",
"label_to_class = {1: '1', 2: '2', 3: '3'}\n",
"\n",
"# Create the class directories if they don't exist\n",
"for class_dir in label_to_class.values():\n",
"    if not os.path.exists(class_dir):\n",
"        os.makedirs(class_dir)\n",
"\n",
"# Iterate over all trials and generate STFT plots\n",
"for i, trial in enumerate(stft_all):\n",
"    # Generate the STFT plot\n",
"    plt.pcolormesh(t, f, abs(trial), cmap='plasma')\n",
"    plt.ylabel('Frequency [Hz]')\n",
"    plt.xlabel('Time [sec]')\n",
"    plt.title(f'Trial {i+1} - Average spectrogram for selected channels')\n",
"    # Get the corresponding label for the trial\n",
"    label = non_zero_labels[i]\n",
"    # Get the class directory for the label\n",
"    class_dir = label_to_class[label]\n",
"     # Save the STFT plot as an image with the label in the filename in the respective
class directory\n",
"    plt.savefig(os.path.join(class_dir, f'trial_{i}_label_{label}_stft.png'))\n",
"    plt.close()\n"
]
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"Layer (type)                 Output Shape              Param #   \n",
"=================================================================\n",
"conv2d_3 (Conv2D)            (None, 222, 222, 32)      896       \n",
"_________________________________________________________________\n",
"max_pooling2d_3 (MaxPooling2 (None, 111, 111, 32)      0         \n",
"_________________________________________________________________\n",
"conv2d_4 (Conv2D)            (None, 109, 109, 64)      18496     \n",
"_________________________________________________________________\n",
"max_pooling2d_4 (MaxPooling2 (None, 54, 54, 64)        0         \n",
"_________________________________________________________________\n",
"conv2d_5 (Conv2D)            (None, 52, 52, 128)       73856     \n",
"_________________________________________________________________\n",
"max_pooling2d_5 (MaxPooling2 (None, 26, 26, 128)       0         \n",
"_________________________________________________________________\n",
"flatten_1 (Flatten)          (None, 86528)             0         \n",
```

```
"_________________________________________________________________\n",
"dense_2 (Dense)              (None, 64)                5537856   \n",
"_________________________________________________________________\n",
"dense_3 (Dense)              (None, 1)                 65        \n",
"=================================================================\n",
"Total params: 5,631,169\n",
"Trainable params: 5,631,169\n",
"Non-trainable params: 0\n",
"_________________________________________________________________\n"
]
}
],
"source": [
"from keras.models import Sequential\n",
"from keras.layers import Conv2D, MaxPooling2D, Flatten, Dense\n",
"\n",
"# Define the input shape of the CNN\n",
"input_shape = (224, 224, 3)\n",
"\n",
"# Define the CNN architecture\n",
"model = Sequential()\n",
"model.add(Conv2D(32, (3, 3), activation='relu', input_shape=input_shape))\n",
"model.add(MaxPooling2D((2, 2)))\n",
"model.add(Conv2D(64, (3, 3), activation='relu'))\n",
"model.add(MaxPooling2D((2, 2)))\n",
"model.add(Conv2D(128, (3, 3), activation='relu'))\n",
"model.add(MaxPooling2D((2, 2)))\n",
"model.add(Flatten())\n",
"model.add(Dense(64, activation='relu'))\n",
"model.add(Dense(1, activation='sigmoid'))\n",
"\n",
"# Compile the model\n",
"model.compile(optimizer='adam', loss='binary_crossentropy', metrics=['accuracy'])\n",
"\n",
"# Print the model summary\n",
"model.summary()\n"
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"Found 109 images belonging to 3 classes.\n"
]
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"import cv2\n",
```

```
"from keras.preprocessing.image import ImageDataGenerator\n",
"\n",
"# Define the path to the directory containing the STFT plot images\n",
"train_dir = 'train'\n",
"test_dir = 'validation'\n",
"\n",
"# Define the image size and batch size\n",
"img_size = (224, 224)\n",
"batch_size = 32\n",
"\n",
"# Define the ImageDataGenerator object for preprocessing the images\n",
"datagen = ImageDataGenerator(\n",
"    rescale=1./255,\n",
"    preprocessing_function=lambda img: cv2.resize(img, img_size))\n",
"\n",
"# Define the training and validation generators\n",
"train_generator = datagen.flow_from_directory(\n",
"    directory=train_dir,\n",
"    target_size=img_size,\n",
"    batch_size=batch_size,\n",
"    class_mode='binary')\n",
"\n",
"valid_generator = datagen.flow_from_directory(\n",
"    directory=test_dir,\n",
"    target_size=img_size,\n",
"    batch_size=batch_size,\n",
"    class_mode='binary')\n"
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"labels batch shape: (32,)\n"
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}
],
"source": [
"for data_batch, labels_batch in train_generator:\n",
"    print('data batch shape:', data_batch.shape)\n",
"    print('labels batch shape:', labels_batch.shape)\n",
"    break"
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{
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```
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0.3608 - val_loss: -1.2969 - val_accuracy: 0.3028\n",
"Epoch 2/30\n",
"27/27 [==============================] - 5s 186ms/step - loss: -0.0973 - accuracy:
0.3608 - val_loss: -3.7730 - val_accuracy: 0.3028\n",
"Epoch 3/30\n",
"27/27 [==============================] - 5s 186ms/step - loss: 0.0857 - accuracy:
0.3643 - val_loss: -3.2833 - val_accuracy: 0.3028\n",
"Epoch 4/30\n",
"27/27 [==============================] - 5s 185ms/step - loss: -2.8298 - accuracy:
0.3608 - val_loss: -17.4720 - val_accuracy: 0.3028\n",
"Epoch 5/30\n",
"27/27 [==============================] - 5s 188ms/step - loss: -17.8126 - accuracy:
0.3737 - val_loss: -121.3252 - val_accuracy: 0.3028\n",
"Epoch 6/30\n",
"27/27 [==============================] - 5s 187ms/step - loss: -194.7553 - accuracy:
0.3608 - val_loss: -1026.3634 - val_accuracy: 0.3028\n",
"Epoch 7/30\n",
"27/27 [==============================] - 5s 190ms/step - loss: -914.5147 - accuracy:
0.3690 - val_loss: -6997.7612 - val_accuracy: 0.3028\n",
"Epoch 8/30\n",
"27/27 [==============================] - 5s 187ms/step - loss: -6816.2866 - accuracy:
0.3608 - val_loss: -39421.5195 - val_accuracy: 0.3028\n",
"Epoch 9/30\n",
" 6/27 [=====>.....................] - ETA: 3s - loss: -36509.7383 - accuracy:
0.3575"
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\u001b[39m=\u001b[39m model\u001b[39m.\u001b[39;49mfit(train_generator,
epochs\u001b[39m=\u001b[39;49m\u001b[39m30\u001b[39;49m,
validation_data\u001b[39m=\u001b[39;49mvalid_generator,
verbose\u001b[39m=\u001b[39;49m\u001b[39m1\u001b[39;49m)\n",
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\u001b[1;32mc:\\Users\\techi\\anaconda3\\envs\\ml\\lib\\site-packages\\keras\\engine\\tr
aining.py:1184\u001b[0m, in \u001b[0;36mModel.fit\u001b[1;34m(self, x, y, batch_size,
epochs, verbose, callbacks, validation_split, validation_data, shuffle, class_weight,
sample_weight, initial_epoch, steps_per_epoch, validation_steps, validation_batch_size,
validation_freq, max_queue_size, workers, use_multiprocessing)\u001b[0m\n\u001b[0;32m
```

```
1177\u001b[0m                                                    \u001b[39mwith\u001b[39;00m
tf\u001b[39m.\u001b[39mprofiler\u001b[39m.\u001b[39mexperimental\u001b[39m.\u001b[39mTra
ce(\n\u001b[0;32m                              1178\u001b[0m
\u001b[39m'\u001b[39m\u001b[39mtrain\u001b[39m\u001b[39m'\u001b[39m,\n\u001b[0;32m
1179\u001b[0m     epoch_num\u001b[39m=\u001b[39mepoch,\n\u001b[0;32m   1180\u001b[0m
step_num\u001b[39m=\u001b[39mstep,\n\u001b[0;32m            1181\u001b[0m
batch_size\u001b[39m=\u001b[39mbatch_size,\n\u001b[0;32m         1182\u001b[0m
_r\u001b[39m=\u001b[39m\u001b[39m1\u001b[39m):\n\u001b[0;32m          1183\u001b[0m
callbacks\u001b[39m.\u001b[39mon_train_batch_begin(step)\n\u001b[1;32m-> 1184\u001b[0m
tmp_logs                                                    \u001b[39m=\u001b[39m
\u001b[39mself\u001b[39;49m\u001b[39m.\u001b[39;49mtrain_function(iterator)\n\u001b[0;32
m                          1185\u001b[0m                            \u001b[39mif\u001b[39;00m
data_handler\u001b[39m.\u001b[39mshould_sync:\n\u001b[0;32m       1186\u001b[0m
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\u001b[1;32mc:\\Users\\techi\\anaconda3\\envs\\ml\\lib\\site-packages\\tensorflow\\pytho
n\\eager\\def_function.py:885\u001b[0m,                                                in
\u001b[0;36mFunction.__call__\u001b[1;34m(self, *args, **kwds)\u001b[0m\n\u001b[0;32m
882\u001b[0m                          compiler                          \u001b[39m=\u001b[39m
\u001b[39m\"\u001b[39m\u001b[39mxla\u001b[39m\u001b[39m\"\u001b[39m
\u001b[39mif\u001b[39;00m       \u001b[39mself\u001b[39m\u001b[39m.\u001b[39m_jit_compile
\u001b[39melse\u001b[39;00m
\u001b[39m\"\u001b[39m\u001b[39mnonXla\u001b[39m\u001b[39m\"\u001b[39m\n\u001b[0;32m
884\u001b[0m                                                    \u001b[39mwith\u001b[39;00m
OptionalXlaContext(\u001b[39mself\u001b[39m\u001b[39m.\u001b[39m_jit_compile):\n\u001b[1
;32m-->        885\u001b[0m                              result         \u001b[39m=\u001b[39m
\u001b[39mself\u001b[39m\u001b[39m.\u001b[39m_call(\u001b[39m*\u001b[39margs,
\u001b[39m*\u001b[39m\u001b[39m*\u001b[39mkwds)\n\u001b[0;32m               887\u001b[0m
new_tracing_count                                           \u001b[39m=\u001b[39m
\u001b[39mself\u001b[39m\u001b[39m.\u001b[39mexperimental_get_tracing_count()\n\u001b[0;
32m             888\u001b[0m   without_tracing   \u001b[39m=\u001b[39m   (tracing_count
\u001b[39m==\u001b[39m new_tracing_count)\n",
"File
\u001b[1;32mc:\\Users\\techi\\anaconda3\\envs\\ml\\lib\\site-packages\\tensorflow\\pytho
n\\eager\\def_function.py:917\u001b[0m, in \u001b[0;36mFunction._call\u001b[1;34m(self,
*args,      **kwds)\u001b[0m\n\u001b[0;32m                        914\u001b[0m
\u001b[39mself\u001b[39m\u001b[39m.\u001b[39m_lock\u001b[39m.\u001b[39mrelease()\n\u001b
[0;32m    915\u001b[0m   \u001b[39m# In this case we have created variables on the first
call, so we run the\u001b[39;00m\n\u001b[0;32m     916\u001b[0m    \u001b[39m# defunned
version which is guaranteed to never create variables.\u001b[39;00m\n\u001b[1;32m-->
917\u001b[0m                                                \u001b[39mreturn\u001b[39;00m
\u001b[39mself\u001b[39m\u001b[39m.\u001b[39m_stateless_fn(\u001b[39m*\u001b[39margs,
\u001b[39m*\u001b[39m\u001b[39m*\u001b[39mkwds)               \u001b[39m#        pylint:
disable=not-callable\u001b[39;00m\n\u001b[0;32m                                 918\u001b[0m
\u001b[39melif\u001b[39;00m     \u001b[39mself\u001b[39m\u001b[39m.\u001b[39m_stateful_fn
\u001b[39mis\u001b[39;00m                                   \u001b[39mnot\u001b[39;00m
\u001b[39mNone\u001b[39;00m:\n\u001b[0;32m      919\u001b[0m     \u001b[39m# Release the
lock early so that multiple threads can perform the call\u001b[39;00m\n\u001b[0;32m
920\u001b[0m    \u001b[39m# in parallel.\u001b[39;00m\n\u001b[0;32m      921\u001b[0m
\u001b[39mself\u001b[39m\u001b[39m.\u001b[39m_lock\u001b[39m.\u001b[39mrelease()\n",
"File
\u001b[1;32mc:\\Users\\techi\\anaconda3\\envs\\ml\\lib\\site-packages\\tensorflow\\pytho
n\\eager\\function.py:3039\u001b[0m, in \u001b[0;36mFunction.__call__\u001b[1;34m(self,
*args,  **kwargs)\u001b[0m\n\u001b[0;32m      3036\u001b[0m  \u001b[39mwith\u001b[39;00m
```

```
\u001b[39mself\u001b[39m\u001b[39m.\u001b[39m_lock:\n\u001b[0;32m      3037\u001b[0m
(graph_function,\n\u001b[0;32m           3038\u001b[0m               filtered_flat_args)
\u001b[39m=\u001b[39m
\u001b[39mself\u001b[39m\u001b[39m.\u001b[39m_maybe_define_function(args,
kwargs)\n\u001b[1;32m-> 3039\u001b[0m           \u001b[39mreturn\u001b[39;00m
graph_function\u001b[39m.\u001b[39;49m_call_flat(\n\u001b[0;32m     3040\u001b[0m
filtered_flat_args,
captured_inputs\u001b[39m=\u001b[39;49mgraph_function\u001b[39m.\u001b[39;49mcaptured_in
puts)\n",
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\u001b[1;32mc:\\Users\\techi\\anaconda3\\envs\\ml\\lib\\site-packages\\tensorflow\\pytho
n\\eager\\function.py:1963\u001b[0m,                                                in
\u001b[0;36mConcreteFunction._call_flat\u001b[1;34m(self,     args,     captured_inputs,
cancellation_manager)\u001b[0m\n\u001b[0;32m       1959\u001b[0m   possible_gradient_type
\u001b[39m=\u001b[39m
gradients_util\u001b[39m.\u001b[39mPossibleTapeGradientTypes(args)\n\u001b[0;32m
1960\u001b[0m  \u001b[39mif\u001b[39;00m  (possible_gradient_type  \u001b[39m==\u001b[39m
gradients_util\u001b[39m.\u001b[39mPOSSIBLE_GRADIENT_TYPES_NONE\n\u001b[0;32m
1961\u001b[0m          \u001b[39mand\u001b[39;00m  executing_eagerly):\n\u001b[0;32m
1962\u001b[0m        \u001b[39m#   No   tape   is   watching;   skip   to   running   the
function.\u001b[39;00m\n\u001b[1;32m-> 1963\u001b[0m       \u001b[39mreturn\u001b[39;00m
\u001b[39mself\u001b[39m\u001b[39m.\u001b[39m_build_call_outputs(\u001b[39mself\u001b[39
;49m\u001b[39m.\u001b[39;49m_inference_function\u001b[39m.\u001b[39;49mcall(\n\u001b[0;3
2m                 1964\u001b[0m                                                ctx,      args,
cancellation_manager\u001b[39m=\u001b[39;49mcancellation_manager))\n\u001b[0;32m
1965\u001b[0m                    forward_backward                    \u001b[39m=\u001b[39m
\u001b[39mself\u001b[39m\u001b[39m.\u001b[39m_select_forward_and_backward_functions(\n\u
001b[0;32m       1966\u001b[0m           args,\n\u001b[0;32m       1967\u001b[0m
possible_gradient_type,\n\u001b[0;32m                1968\u001b[0m
executing_eagerly)\n\u001b[0;32m     1969\u001b[0m  forward_function,  args_with_tangents
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_InterpolateFunctionError(\u001b[39mself\u001b[39m):\n\u001b[0;32m       590\u001b[0m
\u001b[39mif\u001b[39;00m         cancellation_manager         \u001b[39mis\u001b[39;00m
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ctx\u001b[39m=\u001b[39;49mctx)\n\u001b[0;32m                    597\u001b[0m
\u001b[39melse\u001b[39;00m:\n\u001b[0;32m            598\u001b[0m                outputs
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execute\u001b[39m.\u001b[39mexecute_with_cancellation(\n\u001b[0;32m    599\u001b[0m

\u001b[39mstr\u001b[39m(\u001b[39mself\u001b[39m\u001b[39m.\u001b[39msignature\u001b[39m
.\u001b[39mname),\n\u001b[0;32m              600\u001b[0m
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"File \u001b[1;32mc:\\Users\\techi\\anaconda3\\envs\\ml\\lib\\site-packages\\tensorflow\\python\\eager\\execute.py:59\u001b[0m,    in    \u001b[0;36mquick_execute\u001b[1;34m(op_name, num_outputs,  inputs,  attrs,  ctx,  name)\u001b[0m\n\u001b[0;32m          57\u001b[0m \u001b[39mtry\u001b[39;00m:\n\u001b[0;32m                              58\u001b[0m ctx\u001b[39m.\u001b[39mensure_initialized()\n\u001b[1;32m--->  59\u001b[0m      tensors \u001b[39m=\u001b[39m pywrap_tfe\u001b[39m.\u001b[39;49mTFE_Py_Execute(ctx\u001b[39m.\u001b[39m_handle, device_name, op_name,\n\u001b[0;32m     60\u001b[0m  inputs, attrs, num_outputs)\n\u001b[0;32m     61\u001b[0m \u001b[39mexcept\u001b[39;00m core\u001b[39m.\u001b[39m_NotOkStatusException                  \u001b[39mas\u001b[39;00m e:\n\u001b[0;32m                  62\u001b[0m           \u001b[39mif\u001b[39;00m   name \u001b[39mis\u001b[39;00m \u001b[39mnot\u001b[39;00m \u001b[39mNone\u001b[39;00m:\n",
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"from scipy import signal\n",
"import matplotlib.pyplot as plt\n",
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"def plot_power_vs_freq(channel, eeg, fs=200):\n",
"    \"\"\"Extract power (in dB) vs freq graph from a specific channel of EEG data.\n",
"    \n",
"    Args:\n",
"         channel (int): The channel number (0-indexed) for which the power spectrum is to be computed.\n",
"        eeg (ndarray): The EEG data array of shape (num_channels, num_samples).\n",
"        fs (float): The sampling frequency in Hz (default: 200 Hz).\n",
"        \n",
"    Returns:\n",
"        None (displays a plot of power vs frequency).\n",
"    \"\"\"\n",
"    # Select the specific channel of EEG data\n",
"    eeg_channel = eeg[channel, :]\n",
"    \n",
"    # Compute the power spectrum density using Welch's method\n",
"    f, psd = signal.welch(eeg_channel, fs=fs, nperseg=fs*2, nfft=fs*8)\n",
"    \n",
```

```
"    # Convert power to dB scale\n",
"    psd_db = 10 * np.log10(psd)\n",
"    \n",
"    # Plot the power vs frequency graph\n",
"    plt.plot(f, psd_db)\n",
"    plt.title(f\"Power vs Frequency for Channel {channel}\")\n",
"    plt.xlabel(\"Frequency (Hz)\")\n",
"    plt.ylabel(\"Power Spectral Density (dB/Hz)\")\n",
"    plt.show()\n"
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File: epilepsy.ipynb

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"import numpy as np # linear algebra\n",
"import pandas as pd # data processing, CSV file I/O (e.g. pd.read_csv)\n",
"import matplotlib.pyplot as plt\n",
"import seaborn as sn\n",
"import warnings\n",
"warnings.filterwarnings('ignore')\n",
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"clf = SVC()\n",
```

```
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"y_pred_svc = clf.predict(X_test)\n",
"acc_svc = round(clf.score(X_train, y_train) * 100, 2)\n",
"print(\"Accuracy is:\",(str(acc_svc)+'%'))"
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Repository: Hyperparameter-Optimization-CNN-Differential-Evolution

File: README.md

```
# Hyperparameter Optimization of CNN Using Differential Evolution Algorithm
This repository contains the code implementation for the Hyperparameter Optimization of Convolutional Neural Networks for Speech Command Recognition using Differential Evolution

## Introduction

### Differential Evolution:
Differential Evolution (DE) is a population-based optimization algorithm and is a powerful as well as versatile evolutionary algorithm commonly used to solve optimization problems, especially in continuous domains.

DE belongs to the class of evolutionary algorithms that mimic the process of natural selection and evolution. Inspired by the principle of survival of the fittest, DE aims to iteratively improve a population of candidate solutions to find the optimal or near-optimal solution to a given problem.

### Dataset and Problem Statement:
This implementation uses Differential Evolution based Hyperparameter Search for Convolutional Neural Networks for the Google Speech Commands dataset to optimize recognition of speech commands for 8 classes: "down", "go", "left", "no", "right", "stop", "up" and "yes".
The approach is then compared to Optimization of CNN using Genetic Algorithm (GA) and performance of Pre-Trained Deep CNN (DCNN) Models on the same dataset.

## Libraries Used:
- Tensorflow (for CNN Model Architecture, Model Training, Pre-Trained models)
- Librosa (Audio Signal Processing)
- Numpy
- Sklearn (for metrics)
```

File: Speech_Command_Classification_DE.ipynb


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"import numpy as np\n",
"import seaborn as sns\n",
"import tensorflow as tf\n",
"import os\n",
"from scipy.io import wavfile\n",
"import pandas as pd\n",
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"from keras.applications.resnet import ResNet50\n",
"from keras.utils.np_utils import to_categorical\n",
"from sklearn.utils.class_weight import compute_class_weight\n",
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"print('Commands:', commands)\n",
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"filenames = tf.io.gfile.glob(str(data_dir) + '/*/*')\n",
"filenames = tf.random.shuffle(filenames)\n",
"num_samples = len(filenames)\n",
"print('Number of total examples:', num_samples)\n",
"print('Number of examples per label:',\n",
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"  audio, _ = tf.audio.decode_wav(audio_binary)\n",
"  return tf.squeeze(audio, axis=-1)\n",
" \n",
"def get_label(file_path):\n",
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"  # to work in a TensorFlow graph.\n",
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"def get_waveform_and_label(file_path):\n",
"  label = get_label(file_path)\n",
"  print(\"label\")\n",
"  print(label)\n",
"  audio_binary = tf.io.read_file(file_path)\n",
"  waveform = decode_audio(audio_binary)\n",
"  print(\"waveform\")\n",
"  print(waveform)\n",
"  return waveform, label\n",
" \n",
" \n",
" \n",
"AUTOTUNE = tf.data.AUTOTUNE\n",
"files_ds = tf.data.Dataset.from_tensor_slices(train_files)\n",
"waveform_ds = files_ds.map(get_waveform_and_label, num_parallel_calls=AUTOTUNE)\n",
" \n",
" \n",
" \n",
"rows = 3\n",
"cols = 3\n",
"n = rows*cols\n",
```

```
"fig, axes = plt.subplots(rows, cols, figsize=(10, 12))\n",
"for i, (audio, label) in enumerate(waveform_ds.take(n)):\n",
"  r = i // cols\n",
"  c = i % cols\n",
"  ax = axes[r][c]\n",
"  ax.plot(audio.numpy())\n",
"  ax.set_yticks(np.arange(-1.2, 1.2, 0.2))\n",
"  label = label.numpy().decode('utf-8')\n",
"  ax.set_title(label)\n",
" \n",
"plt.show()\n",
" \n",
" \n",
" \n",
"def get_spectrogram(waveform):\n",
"  # Padding for files with less than 16000 samples\n",
"  zero_padding = tf.zeros([16000] - tf.shape(waveform), dtype=tf.float32)\n",
" \n",
"  # Concatenate audio with padding so that all audio clips will be of the \n",
"  # same length\n",
"  waveform = tf.cast(waveform, tf.float32)\n",
"  equal_length = tf.concat([waveform, zero_padding], 0)\n",
"  spectrogram = tf.signal.stft(\n",
"      equal_length, frame_length=255, frame_step=128)\n",
"      \n",
"  spectrogram = tf.abs(spectrogram)\n",
" \n",
"  return spectrogram\n",
" \n",
" \n",
"for waveform, label in waveform_ds.take(1):\n",
"  label = label.numpy().decode('utf-8')\n",
"  spectrogram = get_spectrogram(waveform)\n",
" \n",
"print('Label:', label)\n",
"print('Waveform shape:', waveform.shape)\n",
"print('Spectrogram shape:', spectrogram.shape)\n",
"print('Audio playback')\n",
"display.display(display.Audio(waveform, rate=16000))\n",
" \n",
" \n",
"def plot_spectrogram(spectrogram, ax):\n",
"  # Convert to frequencies to log scale and transpose so that the time is\n",
"  # represented in the x-axis (columns).\n",
"  log_spec = np.log(spectrogram.T)\n",
"  height = log_spec.shape[0]\n",
"  width = log_spec.shape[1]\n",
"  X = np.linspace(0, np.size(spectrogram), num=width, dtype=int)\n",
"  Y = range(height)\n",
"  ax.pcolormesh(X, Y, log_spec)\n",
" \n",
" \n",
"fig, axes = plt.subplots(2, figsize=(12, 8))\n",
"timescale = np.arange(waveform.shape[0])\n",
```

```
"axes[0].plot(timescale, waveform.numpy())\n",
"axes[0].set_title('Waveform')\n",
"axes[0].set_xlim([0, 16000])\n",
"plot_spectrogram(spectrogram.numpy(), axes[1])\n",
"axes[1].set_title('Spectrogram')\n",
"plt.show()\n",
" \n",
" \n",
"def get_spectrogram_and_label_id(audio, label):\n",
"  spectrogram = get_spectrogram(audio)\n",
"  spectrogram = tf.expand_dims(spectrogram, -1)\n",
"  label_id = tf.argmax(label == commands)\n",
"  return spectrogram, label_id\n",
" \n",
" \n",
"spectrogram_ds = waveform_ds.map(\n",
"    get_spectrogram_and_label_id, num_parallel_calls=AUTOTUNE)\n",
" \n",
" \n",
"rows = 3\n",
"cols = 3\n",
"n = rows*cols\n",
"fig, axes = plt.subplots(rows, cols, figsize=(10, 10))\n",
"for i, (spectrogram, label_id) in enumerate(spectrogram_ds.take(n)):\n",
"  r = i // cols\n",
"  c = i % cols\n",
"  ax = axes[r][c]\n",
"  plot_spectrogram(np.squeeze(spectrogram.numpy()), ax)\n",
"  ax.set_title(commands[label_id.numpy()])\n",
"  ax.axis('off')\n",
"  \n",
"plt.show()\n",
" \n",
" \n",
"def preprocess_dataset(files):\n",
"  files_ds = tf.data.Dataset.from_tensor_slices(files)\n",
"  output_ds = files_ds.map(get_waveform_and_label, num_parallel_calls=AUTOTUNE)\n",
"  output_ds = output_ds.map(\n",
"      get_spectrogram_and_label_id,  num_parallel_calls=AUTOTUNE)\n",
"  return output_ds\n",
" \n",
" \n",
"train_ds = spectrogram_ds\n",
"val_ds = preprocess_dataset(val_files)\n",
"test_ds = preprocess_dataset(test_files)\n",
"print(\"test_ds\")\n",
"print(type(train_ds)) \n",
" \n",
"batch_size = 64\n",
"train_ds = train_ds.batch(batch_size)\n",
"val_ds = val_ds.batch(batch_size)\n",
"test_ds = test_ds.batch(batch_size) \n",
" \n",
"train_ds = train_ds.cache().prefetch(AUTOTUNE)\n",
```

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"print(pt.numpy().shape)\n",
"print(en.numpy())"
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"next_element1 = iterator1.get_next()\n",
"pt1 = next_element1[0]\n",
"en1 = next_element1[1]\n",
"print(pt1.numpy().shape)\n",
"print(en1.numpy().shape)"
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"for spectrogram, _ in spectrogram_ds.take(1):\n",
"  input_shape = spectrogram.shape\n",
"print('Input shape:', input_shape)\n",
"num_labels = len(commands)\n",
"\n",
"norm_layer = preprocessing.Normalization()\n",
"norm_layer.adapt(spectrogram_ds.map(lambda x, _: x))"
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"from keras import layers\n",
"from keras import models\n",
"from keras.callbacks import EarlyStopping"
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"def CNN_model(f1, f2, f3, f4, k, a1, a2, d1, d2, op, ep, fitness):\n",
"  model = models.Sequential([\n",
"    layers.Input(shape=input_shape),\n",
"    preprocessing.Resizing(32, 32), \n",
"    norm_layer,\n",
"  ])\n",
"\n",
"                                                    model.add(Conv2D(input_shape=(32,32,
1),filters=f1,kernel_size=(k,k),padding=\"same\", activation=a1))\n",
"  model.add(Conv2D(filters=f1,kernel_size=(k,k),padding=\"same\", activation=a1))\n",
"  model.add(BatchNormalization())\n",
"  model.add(MaxPooling2D(pool_size=(2,2),strides=(1,1)))\n",
"  model.add(Dropout(d1))\n",
"\n",
"  model.add(Conv2D(filters=f2, kernel_size=(k,k), padding=\"same\", activation=a2))\n",
"  model.add(Conv2D(filters=f2, kernel_size=(k,k), padding=\"same\", activation=a2))\n",
"  model.add(BatchNormalization())\n",
"  model.add(MaxPooling2D(pool_size=(2,2),strides=(1,1)))\n",
"  model.add(Dropout(d2))\n",
"\n",
"  model.add(Conv2D(filters=f3, kernel_size=(k,k), padding=\"same\", activation=a2))\n",
"  model.add(Conv2D(filters=f3, kernel_size=(k,k), padding=\"same\", activation=a2))\n",
```

```
"  model.add(Conv2D(filters=f3, kernel_size=(k,k), padding=\"same\", activation=a2))\n",
"  model.add(BatchNormalization())\n",
"  model.add(MaxPooling2D(pool_size=(2,2),strides=(1,1)))\n",
"  model.add(Dropout(d2))\n",
"\n",
"  model.add(Conv2D(filters=f2, kernel_size=(k,k), padding=\"same\", activation=a1))\n",
"  model.add(Conv2D(filters=f2, kernel_size=(k,k), padding=\"same\", activation=a1))\n",
"  model.add(Conv2D(filters=f2, kernel_size=(k,k), padding=\"same\", activation=a1))\n",
"  model.add(BatchNormalization())\n",
"  model.add(MaxPooling2D(pool_size=(2,2),strides=(1,1)))\n",
"  model.add(Dropout(d1))\n",
"\n",
"\n",
"  model.add(Conv2D(filters=f3, kernel_size=(k,k), padding=\"same\", activation=a1))\n",
"  model.add(Conv2D(filters=f3, kernel_size=(k,k), padding=\"same\", activation=a1))\n",
"  model.add(Conv2D(filters=f3, kernel_size=(k,k), padding=\"same\", activation=a1))\n",
"  model.add(BatchNormalization())\n",
"  model.add(MaxPooling2D(pool_size=(2,2),strides=(1,1)))\n",
"  model.add(Dropout(d1))\n",
"\n",
"  model.add(Flatten())\n",
"  model.add(BatchNormalization())\n",
"  model.add(Dense(units=f4,activation=a1))\n",
"  model.add(BatchNormalization())\n",
"  model.add(Dense(units=f4,activation=a1))\n",
"  model.add(Dense(units=num_labels, activation=\"softmax\"))\n",
"\n",
"  model.compile(\n",
"    optimizer=op,\n",
"    loss=tf.keras.losses.SparseCategoricalCrossentropy(from_logits=True),\n",
"    metrics=['accuracy'],\n",
"  )\n",
"\n",
"  EPOCHS = ep\n",
"  \n",
"  history = model.fit(\n",
"    train_ds, \n",
"    validation_data=val_ds,  \n",
"    epochs=EPOCHS,\n",
"    callbacks=tf.keras.callbacks.EarlyStopping(verbose=1, patience=10),\n",
"  )\n",
"                                  fitness.append((history.history[\"val_accuracy\"][-1],
history.history[\"accuracy\"][-1]))\n",
"  return model, history"
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"# Generating the bounds list for every hyperparameter\n",
"bounds = [\n",
"    [16, 32, 64],                                # f1\n",
"    [32, 64, 128],                               # f2\n",
"    [32, 64, 128],                               # f3\n",
"    [128, 256, 512],                             # f4\n",
"    [3, 5],                                       # k\n",
"    [\"relu\", \"selu\", \"elu\"],                        # a1\n",
"    [\"relu\", \"selu\", \"elu\"],                        # a2\n",
"    (0.1, 0.5),                                  # d1\n",
"    (0.1, 0.5),                                  # d2\n",
"    [\"adamax\", \"adadelta\", \"adam\", \"adagrad\"],  # op\n",
"    [50, 60, 70, 80, 90, 100]                    # ep\n",
"]"
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"import random\n",
"\n",
"pop_size = 15\n",
"# Initializing a population of size 15\n",
"population     =     [[random.choice(item)     if     type(item)     is     list     else
round(random.uniform(item[0], item[1]), 1) if type(item) is tuple else item for item in
bounds] for _ in range(pop_size)]\n",
"print(\"Population:\")\n",
"for i, hyperparameters in enumerate(population):\n",
"    print(\"Hyperparameters set\", i+1, \":\", hyperparameters)"
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"def mutation(individual, population, bounds, mutation_factor=0.8):\n",
"\n",
"    population_copy = population.copy()\n",
"    population_copy.remove(individual)\n",
"    a, b, c = random.sample(population_copy, 3)\n",
"\n",
"        \n",
"    # Compute the difference between b and c\n",
"    diff = [round(b_i - c_i, 1) if isinstance(b_i, (int, float)) else b_i for b_i, c_i
in zip(b, c)]\n",
"    \n",
"     # Mutate the individual x by adding the difference multiplied by the mutation
factor\n",
"    mut_individual = [int(a_i + mutation_factor * d) if i in [0,1,2,3,4,10] and \n",
"                          isinstance(a_i, (int, float)) else random.choice(bounds[i])
\n",
"                          if i in [0,1,2,3,4,10] and not isinstance(a_i, (int, float))
else round(a_i + mutation_factor * d, 1)\n",
"                         if isinstance(a_i, (int, float)) else random.choice(bounds[i])
for i,(a_i, d) in enumerate(zip(a, diff))]\n",
"    \n",
"    # make sure that f1, f2, f3, f4 are within (32, 256) bounds\n",
"    for j in range(4):\n",
"        if mut_individual[j] < 32:\n",
"            mut_individual[j] = 32\n",
"        elif mut_individual[j] > 256:\n",
"            mut_individual[j] = 256\n",
"    # Make sure dropout rate stays between (0.1, 0.5)\n",
"    for j in [7,8]:\n",
"        if mut_individual[j] <= 0:\n",
"            mut_individual[j] = 0.1\n",
"        elif mut_individual[j] >= 0.5:\n",
"            mut_individual[j] = 0.5\n",
"            \n",
"    if mut_individual[4] < 3:\n",
"        mut_individual[4] = 3\n",
"            \n",
"            \n",
```

```
"\n",
"    # Min 50 epochs\n",
"    if mut_individual[10] < 50:\n",
"        mut_individual[10] = 50\n",
"    return mut_individual"
]
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"def recombination(individual, population, bounds, CR=0.9):\n",
"    # Mutate the individual first\n",
"    new_individual = mutation(individual, population, bounds)\n",
"    \n",
"     # Pick a random index R in range 1 to n where n is the dimensionality of the problem being optimized.\n",
"    R = random.randint(1, len(bounds))\n",
"    \n",
"    # Compute the agent's potentially new position\n",
"    y = []\n",
"    for i in range(len(bounds)):\n",
"        # Pick a uniformly distributed random number r_i in range(0,1)\n",
"        r = random.uniform(0, 1)\n",
"        if (r < CR) or (i == R):\n",
"            y_i = new_individual[i]\n",
"        else:\n",
"            y_i = individual[i]\n",
"        y.append(y_i)\n",
"    \n",
"     # If f(y)>=f(x) then replace the agent x in the population with the improved or equal candidate solution y\n",
"\n",
"    fitness_y = []\n",
"    fitness_x = []\n",
"    print(y)\n",
"    print(individual)\n",
"    CNN_model(*y, fitness_y)\n",
"    CNN_model(*individual, fitness_x)\n",
"\n",
"    # Comparing based on validation accuracy\n",
"    if fitness_y[0][0] >= fitness_x[0][0]:\n",
"        return y\n",
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"from tensorflow.compat.v1 import InteractiveSession\n",
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"config = ConfigProto()\n",
"config.gpu_options.allow_growth = True\n",
"session = InteractiveSession(config=config)"
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"iterations = 10\n",
"\n",
"with open(\"generation_info.txt\", \"w\") as f:\n",
"    for iterator in range(iterations):  \n",
"        for i in range(len(population)):\n",
"             # The below call to recombination also has the mutation call within it so
it mutates\n",
"            new_individual = recombination(population[i], population, bounds)\n",
"            population[i] = new_individual\n",
"        print(\"Iteration\", iterator + 1, \"over\")\n",
"        print(\"Current population: \", population)\n",
"\n",
"\n",
"        fitness_gen = []\n",
"             for item in population: # Do this for the current population of a
generation\n",
"            CNN_model(*item, fitness_gen)\n",
"            max_valaccuracy_index = fitness_gen.index(max(fitness_gen))\n",
"        f.write(\"Generation: \" + str(iterator + 1) + \"\\n\")\n",
"        f.write(str(fitness_gen[max_valaccuracy_index]) + \"\\n\")\n",
"        f.write(str(population[max_valaccuracy_index]) + \"\\n\")"
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File: Speech_Command_Classification_GA.ipynb

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"from tensorflow.keras import models\n",
"from IPython import display\n",
"import matplotlib.pyplot as plt\n",
"import numpy as np\n",
"import seaborn as sns\n",
"import tensorflow as tf\n",
"import os\n",
"from scipy.io import wavfile\n",
"import pandas as pd\n",
"import matplotlib.pyplot as plt\n",
"import numpy as np\n",
"from keras.layers import Conv2D,MaxPooling2D,Flatten,LSTM,BatchNormalization,GlobalAveragePooling2D\n",
"from keras.layers import Dropout,Dense,TimeDistributed\n",
"from keras.models import Sequential\n",
"from keras.applications.resnet import ResNet50\n",
"from keras.utils.np_utils import to_categorical\n",
"from sklearn.utils.class_weight import compute_class_weight\n",
"from tqdm import tqdm\n",
"from python_speech_features import mfcc\n",
"import pickle\n",
"from keras.callbacks import ModelCheckpoint\n",
" \n",
"import librosa as lr\n",
```

```
" \n",
"data_dir = pathlib.Path('data/mini_speech_commands')\n",
"if not data_dir.exists():\n",
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"      'mini_speech_commands.zip',\n",
"
origin=\"http://storage.googleapis.com/download.tensorflow.org/data/mini_speech_commands
.zip\",\n",
"      extract=True,\n",
"      cache_dir='.', cache_subdir='data')\n",
" \n",
"commands = np.array(tf.io.gfile.listdir(str(data_dir)))\n",
"commands = commands[commands != 'README.md']\n",
"print('Commands:', commands)\n",
" \n",
" \n",
"filenames = tf.io.gfile.glob(str(data_dir) + '/*/*')\n",
"filenames = tf.random.shuffle(filenames)\n",
"num_samples = len(filenames)\n",
"print('Number of total examples:', num_samples)\n",
"print('Number of examples per label:',\n",
"      len(tf.io.gfile.listdir(str(data_dir/commands[0]))))\n",
"print('Example file tensor:', filenames[0])\n",
" \n",
" \n",
" \n",
"train_files = filenames[:6400]\n",
"val_files = filenames[6400: 6400 + 1000]\n",
"test_files = filenames[-600:]\n",
" \n",
"print('Training set size', len(train_files))\n",
"print('Validation set size', len(val_files))\n",
"print('Test set size', len(test_files))\n",
" \n",
" \n",
"def decode_audio(audio_binary):\n",
"  audio, _ = tf.audio.decode_wav(audio_binary)\n",
"  return tf.squeeze(audio, axis=-1)\n",
" \n",
"def get_label(file_path):\n",
"  parts = tf.strings.split(file_path, os.path.sep)\n",
" \n",
"  # Note: You'll use indexing here instead of tuple unpacking to enable this \n",
"  # to work in a TensorFlow graph.\n",
"  return parts[-2] \n",
" \n",
"def get_waveform_and_label(file_path):\n",
"  label = get_label(file_path)\n",
"  print(\"label\")\n",
"  print(label)\n",
"  audio_binary = tf.io.read_file(file_path)\n",
"  waveform = decode_audio(audio_binary)\n",
"  print(\"waveform\")\n",
"  print(waveform)\n",
```

```
"  return waveform, label\n",
" \n",
" \n",
" \n",
"AUTOTUNE = tf.data.AUTOTUNE\n",
"files_ds = tf.data.Dataset.from_tensor_slices(train_files)\n",
"waveform_ds = files_ds.map(get_waveform_and_label, num_parallel_calls=AUTOTUNE)\n",
" \n",
" \n",
" \n",
"rows = 3\n",
"cols = 3\n",
"n = rows*cols\n",
"fig, axes = plt.subplots(rows, cols, figsize=(10, 12))\n",
"for i, (audio, label) in enumerate(waveform_ds.take(n)):\n",
"  r = i // cols\n",
"  c = i % cols\n",
"  ax = axes[r][c]\n",
"  ax.plot(audio.numpy())\n",
"  ax.set_yticks(np.arange(-1.2, 1.2, 0.2))\n",
"  label = label.numpy().decode('utf-8')\n",
"  ax.set_title(label)\n",
" \n",
"plt.show()\n",
" \n",
" \n",
" \n",
"def get_spectrogram(waveform):\n",
"  # Padding for files with less than 16000 samples\n",
"  zero_padding = tf.zeros([16000] - tf.shape(waveform), dtype=tf.float32)\n",
" \n",
"  # Concatenate audio with padding so that all audio clips will be of the \n",
"  # same length\n",
"  waveform = tf.cast(waveform, tf.float32)\n",
"  equal_length = tf.concat([waveform, zero_padding], 0)\n",
"  spectrogram = tf.signal.stft(\n",
"      equal_length, frame_length=255, frame_step=128)\n",
"      \n",
"  spectrogram = tf.abs(spectrogram)\n",
" \n",
"  return spectrogram\n",
" \n",
" \n",
"for waveform, label in waveform_ds.take(1):\n",
"  label = label.numpy().decode('utf-8')\n",
"  spectrogram = get_spectrogram(waveform)\n",
" \n",
"print('Label:', label)\n",
"print('Waveform shape:', waveform.shape)\n",
"print('Spectrogram shape:', spectrogram.shape)\n",
"print('Audio playback')\n",
"display.display(display.Audio(waveform, rate=16000))\n",
" \n",
" \n",
```

```
"def plot_spectrogram(spectrogram, ax):\n",
"  # Convert to frequencies to log scale and transpose so that the time is\n",
"  # represented in the x-axis (columns).\n",
"  log_spec = np.log(spectrogram.T)\n",
"  height = log_spec.shape[0]\n",
"  width = log_spec.shape[1]\n",
"  X = np.linspace(0, np.size(spectrogram), num=width, dtype=int)\n",
"  Y = range(height)\n",
"  ax.pcolormesh(X, Y, log_spec)\n",
" \n",
" \n",
"fig, axes = plt.subplots(2, figsize=(12, 8))\n",
"timescale = np.arange(waveform.shape[0])\n",
"axes[0].plot(timescale, waveform.numpy())\n",
"axes[0].set_title('Waveform')\n",
"axes[0].set_xlim([0, 16000])\n",
"plot_spectrogram(spectrogram.numpy(), axes[1])\n",
"axes[1].set_title('Spectrogram')\n",
"plt.show()\n",
" \n",
" \n",
"def get_spectrogram_and_label_id(audio, label):\n",
"  spectrogram = get_spectrogram(audio)\n",
"  spectrogram = tf.expand_dims(spectrogram, -1)\n",
"  label_id = tf.argmax(label == commands)\n",
"  return spectrogram, label_id\n",
" \n",
" \n",
"spectrogram_ds = waveform_ds.map(\n",
"    get_spectrogram_and_label_id, num_parallel_calls=AUTOTUNE)\n",
" \n",
" \n",
"rows = 3\n",
"cols = 3\n",
"n = rows*cols\n",
"fig, axes = plt.subplots(rows, cols, figsize=(10, 10))\n",
"for i, (spectrogram, label_id) in enumerate(spectrogram_ds.take(n)):\n",
"  r = i // cols\n",
"  c = i % cols\n",
"  ax = axes[r][c]\n",
"  plot_spectrogram(np.squeeze(spectrogram.numpy()), ax)\n",
"  ax.set_title(commands[label_id.numpy()])\n",
"  ax.axis('off')\n",
"  \n",
"plt.show()\n",
" \n",
" \n",
"def preprocess_dataset(files):\n",
"  files_ds = tf.data.Dataset.from_tensor_slices(files)\n",
"  output_ds = files_ds.map(get_waveform_and_label, num_parallel_calls=AUTOTUNE)\n",
"  output_ds = output_ds.map(\n",
"      get_spectrogram_and_label_id,  num_parallel_calls=AUTOTUNE)\n",
"  return output_ds\n",
" \n",
```

```
" \n",
"train_ds = spectrogram_ds\n",
"val_ds = preprocess_dataset(val_files)\n",
"test_ds = preprocess_dataset(test_files)\n",
"print(\"test_ds\")\n",
"print(type(train_ds)) \n",
" \n",
"batch_size = 64\n",
"train_ds = train_ds.batch(batch_size)\n",
"val_ds = val_ds.batch(batch_size)\n",
"test_ds = test_ds.batch(batch_size) \n",
" \n",
"train_ds = train_ds.cache().prefetch(AUTOTUNE)\n",
"val_ds = val_ds.cache().prefetch(AUTOTUNE)\n",
"test_ds = test_ds.cache().prefetch(AUTOTUNE)"
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"next_element = iterator.get_next()\n",
"pt = next_element[0]\n",
"en = next_element[1]\n",
"print(pt.numpy().shape)\n",
"print(en.numpy())"
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"next_element1 = iterator1.get_next()\n",
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"en1 = next_element1[1]\n",
"print(pt1.numpy().shape)\n",
```

```
"print(en1.numpy().shape)"
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"from scipy.io import wavfile\n",
"import pandas as pd\n",
"import matplotlib.pyplot as plt\n",
"import numpy as np\n",
"from keras.layers import Conv2D,MaxPooling2D,Flatten,LSTM,BatchNormalization,GlobalAveragePooling2D\n",
"from keras.layers import Dropout,Dense,TimeDistributed\n",
"from keras.models import Sequential\n",
"from keras.utils.np_utils import to_categorical\n",
"from sklearn.utils.class_weight import compute_class_weight\n",
"from tqdm import tqdm\n",
"from python_speech_features import mfcc\n",
"import pickle\n",
"from keras.callbacks import ModelCheckpoint\n",
"\n",
"import librosa as lr"
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"from tensorflow import keras\n",
"import numpy as np\n"
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"for spectrogram, _ in spectrogram_ds.take(1):\n",
"  input_shape = spectrogram.shape\n",
"print('Input shape:', input_shape)\n",
"num_labels = len(commands)\n",
"\n",
"norm_layer = preprocessing.Normalization()\n",
"norm_layer.adapt(spectrogram_ds.map(lambda x, _: x))"
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"from keras import layers\n",
"from keras import models\n",
"from keras.callbacks import EarlyStopping"
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"def CNN_model( f1, f2, f3, f4, k, a1, a2, d1, d2, op, ep):\n",
"  model = models.Sequential([\n",
"    layers.Input(shape=input_shape),\n",
"    preprocessing.Resizing(32, 32), \n",
"    norm_layer,\n",
"  ])\n",
"\n",
"                                                    model.add(Conv2D(input_shape=(32,32,
1),filters=f1,kernel_size=(k,k),padding=\"same\", activation=a1))\n",
"  model.add(Conv2D(filters=f1,kernel_size=(k,k),padding=\"same\", activation=a1))\n",
"  model.add(BatchNormalization())\n",
"  model.add(MaxPooling2D(pool_size=(2,2),strides=(1,1)))\n",
"  model.add(Dropout(d1))\n",
"\n",
```

```
"  model.add(Conv2D(filters=f2, kernel_size=(k,k), padding=\"same\", activation=a2))\n",
"  model.add(Conv2D(filters=f2, kernel_size=(k,k), padding=\"same\", activation=a2))\n",
"  model.add(BatchNormalization())\n",
"  model.add(MaxPooling2D(pool_size=(2,2),strides=(1,1)))\n",
"  model.add(Dropout(d2))\n",
"\n",
"  model.add(Conv2D(filters=f3, kernel_size=(k,k), padding=\"same\", activation=a2))\n",
"  model.add(Conv2D(filters=f3, kernel_size=(k,k), padding=\"same\", activation=a2))\n",
"  model.add(Conv2D(filters=f3, kernel_size=(k,k), padding=\"same\", activation=a2))\n",
"  model.add(BatchNormalization())\n",
"  model.add(MaxPooling2D(pool_size=(2,2),strides=(1,1)))\n",
"  model.add(Dropout(d2))\n",
"\n",
"  model.add(Conv2D(filters=f2, kernel_size=(k,k), padding=\"same\", activation=a1))\n",
"  model.add(Conv2D(filters=f2, kernel_size=(k,k), padding=\"same\", activation=a1))\n",
"  model.add(Conv2D(filters=f2, kernel_size=(k,k), padding=\"same\", activation=a1))\n",
"  model.add(BatchNormalization())\n",
"  model.add(MaxPooling2D(pool_size=(2,2),strides=(1,1)))\n",
"  model.add(Dropout(d1))\n",
"\n",
"\n",
"  model.add(Conv2D(filters=f3, kernel_size=(k,k), padding=\"same\", activation=a1))\n",
"  model.add(Conv2D(filters=f3, kernel_size=(k,k), padding=\"same\", activation=a1))\n",
"  model.add(Conv2D(filters=f3, kernel_size=(k,k), padding=\"same\", activation=a1))\n",
"  model.add(BatchNormalization())\n",
"  model.add(MaxPooling2D(pool_size=(2,2),strides=(1,1)))\n",
"  model.add(Dropout(d1))\n",
"\n",
"  model.add(Flatten())\n",
"  model.add(BatchNormalization())\n",
"  model.add(Dense(units=f4,activation=a1))\n",
"  model.add(BatchNormalization())\n",
"  model.add(Dense(units=f4,activation=a1))\n",
"  model.add(Dense(units=num_labels, activation=\"softmax\"))\n",
"\n",
"  model.compile(\n",
"    optimizer=op,\n",
"    loss=tf.keras.losses.SparseCategoricalCrossentropy(from_logits=True),\n",
"    metrics=['accuracy'],\n",
"  )\n",
"  EPOCHS = ep\n",
"  history = model.fit(\n",
"    train_ds, \n",
"    validation_data=val_ds,  \n",
"    epochs=EPOCHS,\n",
"    callbacks=tf.keras.callbacks.EarlyStopping(verbose=1, patience=6),\n",
"  )\n",
"  #store history values in global dic.\n",
"  return model, history\n",
"\n",
"\n"
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"from numpy.random import randint"
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"def initialization():  \n",
"  parameters = {}\n",
"  f1 = choice([16, 32, 64])\n",
"  parameters[\"f1\"] = f1\n",
"  f2 = choice([32, 64, 128])\n",
"  parameters[\"f2\"] = f2\n",
"  f3 = choice([32, 64, 128])\n",
"  parameters[\"f3\"] = f3\n",
"  f4 = choice([128, 256, 512])\n",
"  parameters[\"f4\"] = f4\n",
"  k = choice([3,5])\n",
"  parameters[\"k\"] = k\n",
"  a1 = choice([\"relu\", \"selu\", \"elu\"])\n",
"  parameters[\"a1\"] = a1\n",
"  a2 = choice([\"relu\", \"selu\", \"elu\"])\n",
"  parameters[\"a2\"] = a2\n",
"  d1 = round(uniform(0.1, 0.5), 1)\n",
"  parameters[\"d1\"] = d1\n",
"  d2 = round(uniform(0.1, 0.5), 1)\n",
"  parameters[\"d2\"] = d2\n",
"  op = choice([\"adamax\", \"adadelta\", \"adam\", \"adagrad\"])\n",
"  parameters[\"op\"] = op\n",
"  ep = randint(50,100)\n",
"  parameters[\"ep\"] = ep\n",
"  return parameters"
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"def generate_population(n):\n",
"  population = []\n",
"  for i in range(n):\n",
"    chromosome = initialization()\n",
"    population.append(chromosome)\n",
"  return population"
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"# Fitness evaluation metric: Classification Accuracy \n",
"def fitness_evaluation(model):\n",
"  metrics = model.evaluate(test_ds)\n",
"  print(f\"metrics:{metrics}\")\n",
"  return metrics[1]"
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"# Roulette wheel selection method\n",
"def selection(population_fitness):\n",
"  total = sum(population_fitness)a\n",
"  percentage = [round((x/total) * 100) for x in population_fitness]\n",
"  selection_wheel = []\n",
"  for pop_index,num in enumerate(percentage):\n",
"    selection_wheel.extend([pop_index]*num)\n",
"  parent1_ind = choice(selection_wheel)\n",
"  parent2_ind = choice(selection_wheel)\n",
"  return [parent1_ind, parent2_ind]"
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"def crossover(parent1, parent2):\n",
"  child1 = {}\n",
```

```
"  child2 = {}\n",
"\n",
"  child1[\"f1\"] = choice([parent1[\"f1\"], parent2[\"f1\"]])\n",
"  child1[\"f2\"] = choice([parent1[\"f2\"], parent2[\"f2\"]])\n",
"  child1[\"f3\"] = choice([parent1[\"f3\"], parent2[\"f3\"]])\n",
"  child1[\"f4\"] = choice([parent1[\"f4\"], parent2[\"f4\"]])\n",
"\n",
"  child2[\"f1\"] = choice([parent1[\"f1\"], parent2[\"f1\"]])\n",
"  child2[\"f2\"] = choice([parent1[\"f2\"], parent2[\"f2\"]])\n",
"  child2[\"f3\"] = choice([parent1[\"f3\"], parent2[\"f3\"]])\n",
"  child2[\"f4\"] = choice([parent1[\"f4\"], parent2[\"f4\"]])\n",
"\n",
"  child1[\"k\"] = choice([parent1[\"k\"], parent2[\"k\"]])\n",
"  child2[\"k\"] = choice([parent1[\"k\"], parent2[\"k\"]])\n",
"\n",
"  child1[\"a1\"] = parent1[\"a2\"]\n",
"  child2[\"a1\"] = parent2[\"a2\"]\n",
"\n",
"  child1[\"a2\"] = parent2[\"a1\"]\n",
"  child2[\"a2\"] = parent1[\"a1\"]\n",
"\n",
"  child1[\"d1\"] = parent1[\"d1\"]\n",
"  child2[\"d1\"] = parent2[\"d1\"]\n",
"\n",
"  child1[\"d2\"] = parent2[\"d2\"]\n",
"  child2[\"d2\"] = parent1[\"d2\"]\n",
"\n",
"  child1[\"op\"] = parent2[\"op\"]\n",
"  child2[\"op\"] = parent1[\"op\"]\n",
"\n",
"  child1[\"ep\"] = parent1[\"ep\"]\n",
"  child2[\"ep\"] = parent2[\"ep\"]\n",
"  return [child1, child2]"
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"  flag = randint(0,40)\n",
"  if flag <= 20:\n",
"    chromosome[\"ep\"] += randint(0, 10)\n",
"  return chromosome"
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"threshold = 90\n",
"num_pop = 10\n",
"\n",
"population = generate_population(num_pop)\n",
"acc_best = []\n",
"par_total = []\n",
"acc_total = []\n",
"par_best = []\n",
"for generation in range(generations):\n",
"\n",
"  population_fitness = []\n",
"  per1=[]\n",
"  for chromosome in population:\n",
"    f1 = chromosome[\"f1\"]\n",
"    f2 = chromosome[\"f2\"]\n",
"    f3 = chromosome[\"f3\"]\n",
"    f4 = chromosome[\"f4\"]\n",
"    k = chromosome[\"k\"]\n",
"    a1 = chromosome[\"a1\"]\n",
"    a2 = chromosome[\"a2\"]\n",
"    d1 = chromosome[\"d1\"]\n",
"    d2 = chromosome[\"d2\"]\n",
"    op = chromosome[\"op\"]\n",
"    ep = chromosome[\"ep\"]\n",
"\n",
"    try:\n",
"      model = CNN_model(f1, f2, f3, f4, k, a1, a2, d1, d2, op, ep)\n",
"      acc = fitness_evaluation(model)\n",
"      par_total.append(chromosome)\n",
"      acc_total.append(acc)\n",
"      per1.append(chromosome)\n",
"      print(\"Parameters: \", chromosome)\n",
"      print(\"Accuracy: \", round(acc,3))\n",
"    except:\n",
"      acc=0\n",
"      print(\"Parameters: \", chromosome)\n",
"      print(\"Invalid parameters - Build fail\")\n",
"\n",
"    population_fitness.append(acc)\n",
"  print(population_fitness)\n",
"  parents_ind = selection(population_fitness)\n",
"  parent1 = population[parents_ind[0]]\n",
"  parent2 = population[parents_ind[1]]\n",
"\n",
```

```
"  children = crossover(parent1, parent2)\n",
"  child1 = mutation(children[0])\n",
"  child2 = mutation(children[1])\n",
"\n",
"  population.append(child1)\n",
"  population.append(child2)\n",
"\n",
"  print(\"Generation \", generation+1,\" Outcome: \")\n",
"  if max(population_fitness) >= threshold:\n",
"    print(\"Obtained desired accuracy: \", max(population_fitness))\n",
"    break\n",
"  else:\n",
"          print(\"Maximum   accuracy   in   generation   {}   :   {}\".format(generation+1,
max(population_fitness)))\n",
"    max_pop = max(population_fitness)\n",
"    c1=population_fitness.index(max_pop)\n",
"    par_best.append(per1[c1])\n",
"    acc_best.append(max_pop)\n",
"\n",
"  first_min = min(population_fitness)\n",
"  first_min_ind = population_fitness.index(first_min)\n",
"  population.remove(population[first_min_ind])\n",
"  second_min = min(population_fitness)\n",
"  second_min_ind = population_fitness.index(second_min)\n",
"  population.remove(population[second_min_ind])\n",
"\n",
"print(par_total)\n",
"print(acc_total)\n",
"print(par_best)\n",
"print(acc_best)"
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"print(acc_best[var1-1])"
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File: Speech_Command_Classification_PRETRAINED.ipynb

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"from IPython import display\n",
"import matplotlib.pyplot as plt\n",
"import numpy as np\n",
"import seaborn as sns\n",
```

```
"import tensorflow as tf\n",
"import os\n",
"from scipy.io import wavfile\n",
"import pandas as pd\n",
"import matplotlib.pyplot as plt\n",
"from keras.layers import Conv2D,MaxPooling2D,Flatten,LSTM,BatchNormalization,GlobalAveragePooling2D\n",
"from keras.layers import Dropout,Dense,TimeDistributed\n",
"from keras.models import Sequential\n",
"from keras.applications.resnet import ResNet50\n",
"from keras.utils.np_utils import to_categorical\n",
"from sklearn.utils.class_weight import compute_class_weight\n",
"from tqdm import tqdm\n",
"from python_speech_features import mfcc\n",
"import pickle\n",
"from keras.callbacks import ModelCheckpoint\n",
" \n",
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"if not data_dir.exists():\n",
"  tf.keras.utils.get_file(\n",
"      'mini_speech_commands.zip',\n",
"
origin=\"http://storage.googleapis.com/download.tensorflow.org/data/mini_speech_commands
.zip\",\n",
"      extract=True,\n",
"      cache_dir='.', cache_subdir='data')\n",
" \n",
"commands = np.array(tf.io.gfile.listdir(str(data_dir)))\n",
"commands = commands[commands != 'README.md']\n",
"print('Commands:', commands)\n",
" \n",
" \n",
"filenames = tf.io.gfile.glob(str(data_dir) + '/*/*')\n",
"filenames = tf.random.shuffle(filenames)\n",
"num_samples = len(filenames)\n",
"print('Number of total examples:', num_samples)\n",
"print('Number of examples per label:',\n",
"      len(tf.io.gfile.listdir(str(data_dir/commands[0]))))\n",
"print('Example file tensor:', filenames[0])"
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"val_files = filenames[6400: 6400 + 1000]\n",
"test_files = filenames[-600:]\n",
" \n",
"print('Training set size', len(train_files))\n",
"print('Validation set size', len(val_files))\n",
"print('Test set size', len(test_files))\n",
" \n",
" \n",
"def decode_audio(audio_binary):\n",
"  audio, _ = tf.audio.decode_wav(audio_binary)\n",
```

```
"  return tf.squeeze(audio, axis=-1)\n",
" \n",
"def get_label(file_path):\n",
"  parts = tf.strings.split(file_path, os.path.sep)\n",
" \n",
"  # Note: You'll use indexing here instead of tuple unpacking to enable this \n",
"  # to work in a TensorFlow graph.\n",
"  return parts[-2] "
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"  label = get_label(file_path)\n",
"  print(\"label\")\n",
"  print(label)\n",
"  audio_binary = tf.io.read_file(file_path)\n",
"  waveform = decode_audio(audio_binary)\n",
"  print(\"waveform\")\n",
"  print(waveform)\n",
"  return waveform, label\n",
" \n",
" \n",
" \n",
"AUTOTUNE = tf.data.AUTOTUNE\n",
"files_ds = tf.data.Dataset.from_tensor_slices(train_files)\n",
"waveform_ds = files_ds.map(get_waveform_and_label, num_parallel_calls=AUTOTUNE)\n",
" \n",
" \n",
" \n",
"rows = 3\n",
"cols = 3\n",
"n = rows*cols\n",
"fig, axes = plt.subplots(rows, cols, figsize=(10, 12))\n",
"for i, (audio, label) in enumerate(waveform_ds.take(n)):\n",
"  r = i // cols\n",
"  c = i % cols\n",
"  ax = axes[r][c]\n",
"  ax.plot(audio.numpy())\n",
"  ax.set_yticks(np.arange(-1.2, 1.2, 0.2))\n",
"  label = label.numpy().decode('utf-8')\n",
"  ax.set_title(label)\n",
" \n",
```

```
"plt.show()\n",
" \n",
" \n",
" \n",
"def get_spectrogram(waveform):\n",
"  # Padding for files with less than 16000 samples\n",
"  zero_padding = tf.zeros([16000] - tf.shape(waveform), dtype=tf.float32)\n",
" \n",
"  # Concatenate audio with padding so that all audio clips will be of the \n",
"  # same length\n",
"  waveform = tf.cast(waveform, tf.float32)\n",
"  equal_length = tf.concat([waveform, zero_padding], 0)\n",
"  spectrogram = tf.signal.stft(\n",
"      equal_length, frame_length=255, frame_step=128)\n",
"      \n",
"  spectrogram = tf.abs(spectrogram)\n",
" \n",
"  return spectrogram\n",
" \n",
" \n",
"for waveform, label in waveform_ds.take(1):\n",
"  label = label.numpy().decode('utf-8')\n",
"  spectrogram = get_spectrogram(waveform)\n",
" \n",
"print('Label:', label)\n",
"print('Waveform shape:', waveform.shape)\n",
"print('Spectrogram shape:', spectrogram.shape)\n",
"print('Audio playback')\n",
"display.display(display.Audio(waveform, rate=16000))\n",
" \n",
" \n",
"def plot_spectrogram(spectrogram, ax):\n",
"  # Convert to frequencies to log scale and transpose so that the time is\n",
"  # represented in the x-axis (columns).\n",
"  log_spec = np.log(spectrogram.T)\n",
"  height = log_spec.shape[0]\n",
"  width = log_spec.shape[1]\n",
"  X = np.linspace(0, np.size(spectrogram), num=width, dtype=int)\n",
"  Y = range(height)\n",
"  ax.pcolormesh(X, Y, log_spec)\n",
" \n",
" \n",
"fig, axes = plt.subplots(2, figsize=(12, 8))\n",
"timescale = np.arange(waveform.shape[0])\n",
"axes[0].plot(timescale, waveform.numpy())\n",
"axes[0].set_title('Waveform')\n",
"axes[0].set_xlim([0, 16000])\n",
"plot_spectrogram(spectrogram.numpy(), axes[1])\n",
"axes[1].set_title('Spectrogram')\n",
"plt.show()\n",
" \n",
" \n",
"def get_spectrogram_and_label_id(audio, label):\n",
"  spectrogram = get_spectrogram(audio)\n",
```

```
"  spectrogram = tf.expand_dims(spectrogram, -1)\n",
"  label_id = tf.argmax(label == commands)\n",
"  return spectrogram, label_id\n",
" \n",
" \n",
"spectrogram_ds = waveform_ds.map(\n",
"    get_spectrogram_and_label_id, num_parallel_calls=AUTOTUNE)\n",
" \n",
" \n",
"rows = 3\n",
"cols = 3\n",
"n = rows*cols\n",
"fig, axes = plt.subplots(rows, cols, figsize=(10, 10))\n",
"for i, (spectrogram, label_id) in enumerate(spectrogram_ds.take(n)):\n",
"  r = i // cols\n",
"  c = i % cols\n",
"  ax = axes[r][c]\n",
"  plot_spectrogram(np.squeeze(spectrogram.numpy()), ax)\n",
"  ax.set_title(commands[label_id.numpy()])\n",
"  ax.axis('off')\n",
"  \n",
"plt.show()\n",
" \n",
" \n",
"def preprocess_dataset(files):\n",
"  files_ds = tf.data.Dataset.from_tensor_slices(files)\n",
"  output_ds = files_ds.map(get_waveform_and_label, num_parallel_calls=AUTOTUNE)\n",
"  output_ds = output_ds.map(\n",
"      get_spectrogram_and_label_id,  num_parallel_calls=AUTOTUNE)\n",
"  return output_ds\n",
" \n",
" \n",
"train_ds = spectrogram_ds\n",
"val_ds = preprocess_dataset(val_files)\n",
"test_ds = preprocess_dataset(test_files)\n",
"print(\"test_ds\")\n",
"print(type(train_ds)) \n",
" \n",
"batch_size = 64\n",
"train_ds = train_ds.batch(batch_size)\n",
"val_ds = val_ds.batch(batch_size)\n",
"test_ds = test_ds.batch(batch_size) \n",
" \n",
"train_ds = train_ds.cache().prefetch(AUTOTUNE)\n",
"val_ds = val_ds.cache().prefetch(AUTOTUNE)\n",
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"en = next_element[1]\n",
"print(pt.numpy().shape)\n",
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"print(pt1.numpy().shape)\n",
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"for spectrogram, _ in spectrogram_ds.take(1):\n",
"  input_shape = spectrogram.shape\n",
"print('Input shape:', input_shape)\n",
"num_labels = len(commands)\n",
"\n",
"norm_layer = preprocessing.Normalization()\n",
"norm_layer.adapt(spectrogram_ds.map(lambda x, _: x))"
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"from keras.callbacks import EarlyStopping"
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"    spectrogram = tf.repeat(spectrogram, repeats=3, axis=-1)\n",
"    return spectrogram, label\n",
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"spectrogram_ds = spectrogram_ds.map(preprocess)\n"
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"train_ds = spectrogram_ds.skip(num_val_samples)\n",
"val_ds = spectrogram_ds.take(num_val_samples)\n",
"test_split = 0.6\n",
"# Further split val_ds into val_ds and test_ds\n",
"num_test_samples = int(num_val_samples * test_split)\n",
"test_ds = val_ds.take(num_test_samples)\n",
"val_ds = val_ds.skip(num_test_samples)\n",
"\n",
"# Set batch size and shuffle the train_ds\n",
"batch_size = 64\n",
"train_ds = train_ds.shuffle(buffer_size=1000).batch(batch_size)\n",
"test_ds = test_ds.batch(batch_size)\n",
"val_ds = val_ds.batch(batch_size)\n"
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"def get_label(spectrogram, label):\n",
"    return label\n",
"\n",
"# Map the get_label function to the train_ds to extract the labels\n",
"train_labels_ds = train_ds.map(get_label)\n"
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"from tensorflow.keras import models\n",
"from tensorflow.keras import optimizers\n",
"from tensorflow.keras.applications import VGG19\n",
"from tensorflow.keras.applications import VGG16\n",
"from tensorflow.keras.applications import ResNet50\n",
"from tensorflow.keras.applications import InceptionV3\n",
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"# VGG19\n",
"# Define the input shape\n",
"input_shape = (124, 129, 3)\n",
"\n",
"# Define the VGG19 model with pre-trained weights\n",
"base_model = VGG19(weights='imagenet', include_top=False, input_shape=input_shape)\n",
"\n",
"# Freeze all layers in the base model\n",
"for layer in base_model.layers:\n",
"    layer.trainable = False\n",
"\n",
"# Add a custom head to the model\n",
"x = layers.Flatten()(base_model.output)\n",
"x = layers.Dense(256, activation='relu')(x)\n",
"x = layers.Dropout(0.5)(x)\n",
"output = layers.Dense(num_labels, activation='softmax')(x)\n",
```

```
"\n",
"# Compile the model\n",
"vgg19_model = models.Model(inputs=base_model.input, outputs=output)\n",
"vgg19_model.compile(loss='sparse_categorical_crossentropy',
optimizer=optimizers.Adam(learning_rate=0.001), metrics=['accuracy'])\n",
"\n",
"print(\"VGG19\")\n",
"# Train the model on the train dataset\n",
"vgg19_model.fit(train_ds,               epochs=50,               validation_data=val_ds,
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"\n",
"# Define the VGG16 model with pre-trained weights\n",
"base_model = VGG16(weights='imagenet', include_top=False, input_shape=input_shape)\n",
"\n",
"# Freeze all layers in the base model\n",
"for layer in base_model.layers:\n",
"    layer.trainable = False\n",
"\n",
"# Add a custom head to the model\n",
"x = layers.Flatten()(base_model.output)\n",
"x = layers.Dense(256, activation='relu')(x)\n",
"x = layers.Dropout(0.5)(x)\n",
"output = layers.Dense(num_labels, activation='softmax')(x)\n",
"\n",
"# Compile the model\n",
"vgg16_model = models.Model(inputs=base_model.input, outputs=output)\n",
"vgg16_model.compile(loss='sparse_categorical_crossentropy',
optimizer=optimizers.Adam(learning_rate=0.001), metrics=['accuracy'])\n",
"\n",
"print(\"VGG16\")\n",
"# Train the model on the train dataset\n",
"vgg16_model.fit(train_ds,               epochs=50,               validation_data=val_ds,
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"# Define the input shape\n",
"input_shape = (124, 129, 3)\n",
"\n",
"# Define the ResNet50 model with pre-trained weights\n",
"base_model          =          ResNet50(weights='imagenet',          include_top=False,
input_shape=input_shape)\n",
"\n",
"# Freeze all layers in the base model\n",
"for layer in base_model.layers:\n",
"    layer.trainable = True\n",
"\n",
"# Add a custom head to the model\n",
"x = layers.GlobalAveragePooling2D()(base_model.output)\n",
"x = layers.Dense(256, activation='relu')(x)\n",
"x = layers.Dropout(0.5)(x)\n",
"output = layers.Dense(num_labels, activation='softmax')(x)\n",
"\n",
"# Compile the model\n",
"resnet_model = models.Model(inputs=base_model.input, outputs=output)\n",
"resnet_model.compile(loss='sparse_categorical_crossentropy',
optimizer=optimizers.Adam(learning_rate=0.00015), metrics=['accuracy'])\n",
"\n",
"\n",
"print(\"ResNet50\")\n",
"# Train the model on the train dataset\n",
"resnet_model.fit(train_ds,              epochs=100,              validation_data=val_ds,
callbacks=tf.keras.callbacks.EarlyStopping(verbose=1, patience=1))\n"
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"# INCEPTIONV3\n",
"\n",
```

```
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"\n",
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"\n",
"# Freeze all layers in the base model\n",
"for layer in base_model.layers:\n",
"    layer.trainable = True\n",
"\n",
"# Add a custom head to the model\n",
"x = layers.GlobalAveragePooling2D()(base_model.output)\n",
"x = layers.Dense(256, activation='relu')(x)\n",
"x = layers.Dropout(0.5)(x)\n",
"output = layers.Dense(num_labels, activation='softmax')(x)\n",
"\n",
"# Compile the model\n",
"inception_model = models.Model(inputs=base_model.input, outputs=output)\n",
"inception_model.compile(loss='sparse_categorical_crossentropy',
optimizer=optimizers.Adam(learning_rate=0.00017), metrics=['accuracy'])\n",
"\n",
"print(\"InceptionV3\")\n",
"# Train the model on the train dataset\n",
"inception_model.fit(train_ds,             epochs=100,             validation_data=val_ds,
callbacks=tf.keras.callbacks.EarlyStopping(verbose=1, patience=1))\n"
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"\n",
"# Define the input shape\n",
"input_shape = (124, 129, 3)\n",
"\n",
"# Define the Xception model with pre-trained weights\n",
"base_model          =          Xception(weights='imagenet',          include_top=False,
input_shape=input_shape)\n",
"\n",
"# Freeze all layers in the base model\n",
"for layer in base_model.layers:\n",
"    layer.trainable = True\n",
"\n",
"# Add a custom head to the model\n",
```

```
"x = layers.Flatten()(base_model.output)\n",
"x = layers.Dense(256, activation='relu')(x)\n",
"x = layers.Dropout(0.5)(x)\n",
"output = layers.Dense(num_labels, activation='softmax')(x)\n",
"\n",
"# Compile the model\n",
"xception_model = models.Model(inputs=base_model.input, outputs=output)\n",
"xception_model.compile(loss='sparse_categorical_crossentropy',
optimizer=optimizers.Adam(learning_rate=0.00001), metrics=['accuracy'])\n",
"\n",
"print(\"Xception\")\n",
"# Train the model on the train dataset\n",
"xception_model.fit(train_ds,              epochs=80,              validation_data=val_ds,
callbacks=tf.keras.callbacks.EarlyStopping(verbose=1, patience=1))\n"
]
}
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```

Repository: moviepp

File: README.md

```
MOVIE++
===

Getting recommendations for movies is hard. There's just so much to choose from once you open up IMDb!

So I present my (first!) project, MOVIE++, a movie recommender system using Singular Value Decomposition Matrix Factorization Algorithms and item-based Collaborative Filtering.
It takes a movie name as user input through the form, and spits out 15 recommended movies based on my Machine Learning model.

## Live Demo:
Deployed at: [MOVIE++](https://techie5879.github.io/moviepp/) (Using Github Pages)
The deployed verion uses an SVD model item-based CF recommender system (same as the one detailed in the main code), but it has been trained on a smaller dataset to reduce model file size for deployment. It has been trained using the smaller 100K MovieLens small-latest dataset [MovieLens Small-Latest Permalink](https://grouplens.org/datasets/movielens/latest/). It won't provide the same recommendations as the model trained using the 25M Dataset does, but I've tuned the hyperparameters to give recommendations that seem good enough.

## Technologies Used:

### Frontend:
- ReactJS
- CSS

### Backend:
- Flask API

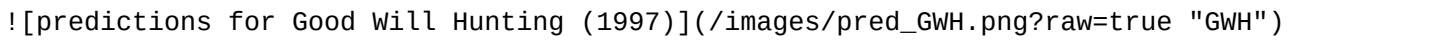
### Model Training:
- Surprise (Python Library)
- Scikit-learn (Python Library)

## Screenshots:
### Home page:
![Home page](/images/home.png?raw=true "Home Page")
### Autocomplete suggestions for movies:

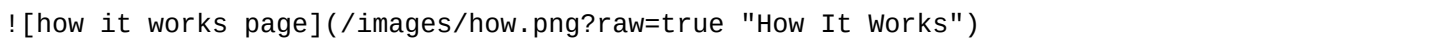
![suggestions](/images/suggestions.png?raw=true "Home Page_Suggestions")

### Predictions page for The Dark Knight (2008):
---
![predictions for The Dark Knight (2008)](/images/pred_TDK.png?raw=true "TDK")

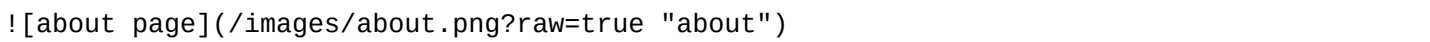

### Predictions page for Good Will Hunting (1997):
```



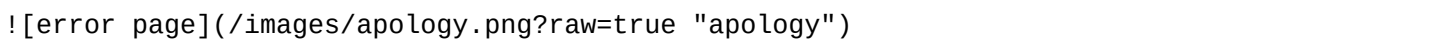
How It Works Page:



About Page:



Error Page (for movie not found):



Usage:

1. User types name of movie, selects a movie from the suggestions list, and clicks the Recommend! button
2. A page with the details of the chosen movie and list of predicted movies with links to their IMDb Pages is displayed.
3. A user can click on the Poster of any movie to be taken to it's respective IMDb Page

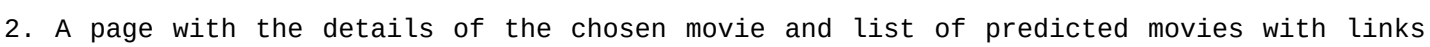
How It Works:

The SVD model was first trained using the Surprise Library in Python. The training was done using the MovieLens 25M dataset provided by GroupLens (permalink: [MovieLens 25M dataset](https://grouplens.org/datasets/movielens/25m/))
It contains approximately 25M ratings across 62423 movies.

The Matrix Factorization method of Singular Value Decomposition is a Dimensionality Reduction method which breaks down the user-product preference matrix into a user-feature and item-feature matrix. This reduces the dimension of the user-product preference space.

Then, SciPy vector cosine distance was used to compute similarity of items (movies) by taking the dot product of the latent feature vectors corresponding to each movie.

The similarity is calculated over all the movies available in the database, and the 15 most similar movies are returned by the Flask API, along with information from the TMDB (The Movie Database) API which has been used to get the poster paths and IMDb IDs of the movies. These are received by the React Frontend and then rendered in the web browser.

Here's a diagram describing the Data Flow:


For running on localhost:
- To get this project up and running on your localhost, you need to have NodeJS installed. Also the requirements from `requirements.txt` must be installed in the environment you're working on. The movielens dataset must be downloaded too and movies.csv, links.csv and ratings.csv are to be placed in the project directory.
- Then `cd` into the repo directory, and use the `svd_train.ipynb` to generate the

model.
- Then use `npm start` to start the frontend, and `flask run` to get the backend running

Challenges Faced and Things Learned:
Since this was my first ML project (and first project in general), getting to this point was quite a challenge. First, I had to learn about how recommender systems worked, types of recommender systems (like Content-based, Collaborative Filtering). It was a continuous process of googling, finding something new, and trying to learn how to implement that! Then I came across the Netflix Prize ([More about Netflix Challenge here](https://en.wikipedia.org/wiki/Netflix_Prize) and [here](https://datajobs.com/data-science-repo/Recommender-Systems-[Netflix].pdf)), where a modification of a certain technique called SVD which was quite a bit more efficient than other models grabbed the prize. So naturally I was drawn to learn what it is, and how to implement it. I finally settled on a SVD and item-based Collaborative Filtering model to recommend movies.

Then, the next step was training the model, and there was trouble here too. Although the RMSE error was very respectable, the recommendations didnt look that relevant - there was obscure noise in the data. I used a very primitive method and removed some of the noise by leaving out some obscure movies and their ratings while training. This can probably be improved further to reduce the noise more efficiently. This resulted in very relevant recommendations, so I was satisfied.

Next was the frontend. Even though I had some basic HTML, CSS, Javascript knowledge, I didn't really have any experience. So I decided to learn ReactJS instead of just using HTML Templates with Jinja syntax. I learned how to create multi-page React Websites, conditional routing, use of hooks, states, and requesting and handling data. I also implemented an autocomplete feature in the form.

Deployment of this app to a hosting service is a bit of a difficulty as of now, as the model file generated was of 300+ MB. Hosting such a large model online to get predictions along with a Flask server is quite a problem.
The project has been deployed by making the model smaller by training it on the movielens-small-latest dataset.

File: app.py

```
import os
from dotenv import load_dotenv
from flask import Flask, request
from predict import get_recs
import urllib.request

import json
load_dotenv()

API_KEY = os.getenv("API_KEY")

app = Flask(__name__)

obj = {}
```

```
imdb_result = {}


@app.route('/movies')
def movies():
with open("movies_obj.json") as file:
movies_obj = json.load(file)

movies = movies_obj["title"]
return movies



@app.route('/predictor', methods=["POST"])
def predict():

if request.method == "POST":

movie = request.get_json()
movie_title = movie["title"]
# If movie title isnt empty
if movie_title:
predictions = get_recs(movie_title)
# If movie title in csv list
if predictions:

final = json.loads(predictions)
rec_titles = final["imdbId"]
obj.update(rec_titles)

# If movie title isnt in csv list
for i in range(16):
imdbId = (list(obj.values()))[i]
url                                                                                    =
"https://api.themoviedb.org/3/find/tt{}?api_key={}&language=en-US&external_source=imdb_i
d".format(imdbId, API_KEY)
response = urllib.request.urlopen(url)
data = response.read()
intermediate = json.loads(data)
intermediate["imdbId"] = imdbId
final = json.dumps(intermediate)
imdb_result[i] = json.loads(final)

return imdb_result
else:

return None
```

File: csvtojson.ipynb

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```

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"      <th>1</th>\n",
"      <td>Jumanji (1995)</td>\n",
"    </tr>\n",
"    <tr>\n",
"      <th>2</th>\n",
"      <td>Grumpier Old Men (1995)</td>\n",
"    </tr>\n",
"    <tr>\n",
"      <th>3</th>\n",
```

```
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"    </tr>\n",
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"      <td>We (2018)</td>\n",
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"    </tr>\n",
"    <tr>\n",
"      <th>62420</th>\n",
"      <td>Bad Poems (2018)</td>\n",
"    </tr>\n",
"    <tr>\n",
"      <th>62421</th>\n",
"      <td>A Girl Thing (2001)</td>\n",
"    </tr>\n",
"    <tr>\n",
"      <th>62422</th>\n",
"      <td>Women of Devil's Island (1962)</td>\n",
"    </tr>\n",
"  </tbody>\n",
"</table>\n",
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"1                         Jumanji (1995)\n",
"2                Grumpier Old Men (1995)\n",
"3               Waiting to Exhale (1995)\n",
"4      Father of the Bride Part II (1995)\n",
"...                                   ...\n",
"62418                          We (2018)\n",
"62419          Window of the Soul (2001)\n",
"62420                   Bad Poems (2018)\n",
"62421                A Girl Thing (2001)\n",
"62422      Women of Devil's Island (1962)\n",
"\n",
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"df"
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]
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```

```
}
```

Repository: qiskit-practice

File: 1_Single Qubits.ipynb


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"import os\n",
"from qiskit import *\n",
"from qiskit_ibm_provider import IBMProvider\n",
"from math import *\n",
"import qiskit\n"
]
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"### Initial Setup for Qiskit, loading accounts and Providers"
]
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'qiskit-ibmq-provider':    '0.20.2',    'qiskit':    '0.43.0',    'qiskit-nature':    None,
'qiskit-finance': None, 'qiskit-optimization': None, 'qiskit-machine-learning': None}"
]
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{
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```

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]
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{
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"QuantumRegister(1, 'q')"
]
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}
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"# Initializing a single qubit to |0> and naming the qubit as 'q'\n",
"qr = QuantumRegister(1, \"q\")\n",
"qr"
]
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{
"data": {
```

```
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]
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????????????????????????????????\n",
"q: ? Initialize(0.70711,0.70711) ?\n",
"   ????????????????????????????????</pre>"
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"   ????????????????????????????????"
]
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"desired_state = [1/sqrt(2), 1/sqrt(2)]\n",
"qr = QuantumRegister(1, \"q\")\n",
"qc = QuantumCircuit(qr)\n",
"qc.initialize(desired_state, qr[0])\n",
"qc.draw()"
]
},
{
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"#### Some basic gates are as follows\n",
"\n",
```

```
"$$X = \\begin{bmatrix} 0 & 1 \\\\ 1 & 0 \\end{bmatrix}$$\n",
"$$Y = \\begin{bmatrix} 0 & -i \\\\ i & 0 \\end{bmatrix}$$\n",
"$$Z = \\begin{bmatrix} 1 & 0 \\\\ 0 & -1 \\end{bmatrix}$$\n",
"$$H = \\frac{1}{\\sqrt2}\\begin{bmatrix} 1 & 1 \\\\ 1 & -1 \\end{bmatrix}$$\n",
"$$S = \\begin{bmatrix} 1 & 0 \\\\ 0 & i \\end{bmatrix}$$\n",
"$$T = \\begin{bmatrix} 1 & 0 \\\\ 0 & e^{i\\pi /4} \\end{bmatrix}$$\n",
"\n",
"##### Some useful states that can also be used as basis since they are orthogonal are:\n",
"\n",
"$$| + \\rangle = \\frac{1}{\\sqrt2}(|0\\rangle + |1\\rangle)$$\n",
"$$| - \\rangle = \\frac{1}{\\sqrt2}(|0\\rangle - |1\\rangle)$$"
]
},
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"### A quantum circuit implementing gates H, Z, X\n",
"\n",
"This circuit uses H, Z, and X gates in that order to obtain the state $\\frac{1}{\\sqrt2}(|1\\rangle - |0\\rangle)$ from $|0\\rangle$\n",
"\n",
"First, by default, qr is initialized to $|0\\rangle$, and on application of H, we obtained $\\frac{1}{\\sqrt2}(|0\\rangle + |1\\rangle)$  \n",
"Then application of Z gate makes qr evolve to $\\frac{1}{\\sqrt2}(|0\\rangle - |1\\rangle)$  \n",
"Finally, X acts similar to the classical NOT gate and qr finally evolves to $\\frac{1}{\\sqrt2}(|1\\rangle - |0\\rangle)$"
]
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"### Generalization of single qubit gates\n",
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"$$U_3(\\theta, \\phi, \\lambda) = \\begin{bmatrix} \\cos \\frac{\\theta}{2} & -e^{i\\lambda}\\sin \\frac{\\theta}{2} \\\\[6pt] e^{i\\phi}\\sin \\frac{\\theta}{2} & e^{i(\\phi + \\lambda)\\cos \\frac{\\theta}{2}} \\end{bmatrix}$$ \n",
"We can express X gate as $U_3(\\pi, 0, \\pi)$, H gate as $U_3(\\frac{\\pi}{2}, 0, \\pi)$\n",
"\n",
"#### Other common parametric gates $U_1$ and $U_2$ are as follows:\n",
"$$U_1(\\lambda) = \\begin{bmatrix} 1 & 0 \\\\[6pt] 0 & e^{i\\lambda} \\end{bmatrix} = U_3(0, 0, \\lambda)$$\n",
"\n",
"$$U_2(\\phi, \\lambda) = \\frac{1}{\\sqrt2}\\begin{bmatrix} 1 & -e^{i\\lambda} \\\\[6pt] e^{i\\phi} & e^{i(\\phi + \\lambda)} \\end{bmatrix} = U_3(\\frac{\\pi}{2}, \\phi, \\lambda)$$\n"
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"qc.u(pi, 0, pi, qr) #u3 gate"
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"We flip the qubit qr and measure it 100 times. Since initial state of qr was $|0\\rangle$, flipping it makes its state $|1\\rangle$, so measuring it 100 times should give us the state $|1\\rangle$ 100 times.  \n",
"This measurement is performed in computational basis, and qubit will collapse to one of $|0\\rangle$ or $|1\\rangle$ on measurement"
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"cr = ClassicalRegister(1)  # Helps in storing the output of the qubit measurement\n",
"qc = QuantumCircuit(qr, cr)\n",
"\n",
"# Flipping qubit qr and measuring it\n",
"qc.x(qr)\n",
"qc.measure(qr, cr) # Measure the qubit qr and store the ouput in cr\n",
"\n",
"# Executing on backend\n",
"backend = Aer.get_backend('qasm_simulator')\n",
"qjob = execute(qc, backend, shots=100) # shots specifies the number of times the circuit (including measurement) will be repeated\n",
"# Resulting measurement statistic will be stored in result object\n",
"# This mimics measuring 100 qubits in computational basis\n",
"measurement = qjob.result().get_counts()\n",
"print(measurement)"
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"#### Measuring in Hadamard Basis\n",
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"We can measure the state of the qubit in any orthogonal basis. If we want to know whether the output is $|+\\rangle$ or $|-\\rangle$, then we have to measure in the Hadamard Basis: $\\{ |+\\rangle, |-\\rangle \\}$  \n",
"Any state $|\\phi \\rangle = \\alpha |0\\rangle + \\beta |1\\rangle$ can be represented in Hadamard basis using the following:\n",
"$$|\\phi \\rangle = \\frac{(\\alpha + \\beta)}{\\sqrt2} |+\\rangle + \\frac{(\\alpha - \\beta)}{\\sqrt2} |-\\rangle$$\n",
"\n",
"Now, if we apply $H^{\\dagger}$ on $|\\phi\\rangle$, we have:\n",
"$$H^{\\dagger} |\\phi \\rangle = \\frac{(\\alpha + \\beta)}{\\sqrt2} |0\\rangle + \\frac{(\\alpha - \\beta)}{\\sqrt2} |1\\rangle$$\n",
"i.e., $H^{\\dagger}$ maps $|+\\rangle$ to $|0\\rangle$ and $|-\\rangle$ to $|1\\rangle$\n",
"\n",
"So, measuring $H^\\dagger |\\phi \\rangle$ in computational basis is the same as measuring $|\\phi \\rangle$ in Hadamard Basis  \n",
"This is called Transformation of Basis\n",
"\n",
"Note: $H = H^\\dagger$"
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"qc.x(qr)\n",
"# Now we need to measure whether output is one of the Hadamard Basis\n",
"# So first apply H^dagger = H on qr to transform to computational basis\n",
"# In output, 0 corresponds to + and 1 corresponds to -\n",
"\n",
"qc.h(qr)\n",
"qc.measure(qr, cr)\n",
"\n",
"backend = Aer.get_backend('qasm_simulator')\n",
"qjob = execute(qc, backend) # Default shots = 1024\n",
"counts = qjob.result().get_counts()\n",
"print(counts)\n"
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"Slight deviation due to randomness, otherwise should have been prob = $\\frac{1}{2}$ for each exactly  \n",
"Note: In output, $|0\\rangle$ corresponds to $|+\\rangle$ and $|1\\rangle$ corresponds to $|-\\rangle$"
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"from math import *\n",
"import qiskit\n",
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"provider = IBMProvider()"
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"## Quantum True Random Number Generator (QTRNG)\n",
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"Hadamard gate and measurement in computational basis will give rise to true random sequences (due to inherent property of randomness of quantum states)  \n",
"This isn't possible with a classical scenario with PRNG (Pseudo Random Number Generators)"
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"\n",
"    qc.h(q)\n",
"    qc.measure(q, c)\n",
"\n",
"    backend = Aer.get_backend('qasm_simulator')\n",
"    qjob = execute(qc, backend, shots=1)\n",
"    counts = qjob.result().get_counts()\n",
"    for key in counts.keys():\n",
"        print(key)\n"
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File: 3_Multiple Qubits.ipynb

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"from math import *\n",
"import qiskit\n",
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"provider = IBMProvider()"
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"## Multiple Qubits\n",
"\n",
"For two qubits, we can have a superposition of the 4 states:\n",
"$$|\\psi \\rangle = \\alpha_0 |00\\rangle + \\alpha_1 |01\\rangle + \\alpha_2 |10\\rangle + \\alpha_3 |11\\rangle $$\n",
"Amplitude of $|\\psi\\rangle$ is denoted as a column vector\n",
"\n",
"$$|\\psi \\rangle = \\begin{bmatrix}\\alpha_0 \\\\ \\alpha_1 \\\\ \\alpha_2 \\\\ \\alpha_3\\end{bmatrix}$$\n",
"\n",
"$|ab\\rangle$ denotes the tensor product $|a\\rangle \\otimes |b\\rangle$ \n",
"For two vectors $|a\\rangle, |b\\rangle$\n",
"\n",
"$$|a\\rangle = \\begin{bmatrix}a_1 \\\\ a_2 \\\\ \\vdots \\\\ a_n\\end{bmatrix}, |b\\rangle = \\begin{bmatrix}b_1 \\\\ b_2 \\\\ \\vdots \\\\ b_m\\end{bmatrix}$$\n",
"$$|a\\rangle \\otimes |b\\rangle = \\begin{bmatrix}a_1 \\cdot b_1 \\\\ \\vdots \\\\ a_1\\cdot b_m \\\\ \\vdots \\\\ a_n\\cdot b_1 \\\\ \\vdots \\\\ a_n\\cdot b_m\\end{bmatrix}$$\n",
"\n",
"Dimension of tensor product is $(n\\cdot m) \\times 1$\n",
```

```
"\n",
"Tensor Product of two matrices $A = (a_{ij})_{m\\times n}, B = (b_{ij})_{p\\times q}$ is given by:\n",
"$$A\\otimes B = \\begin{bmatrix}a_{11}B & a_{12}B & \\dots & a_{1n}B \\\\a_{12}B & a_{22}B & \\dots & a_{2n}B \\\\ \\vdots & & \\ddots & \\vdots \\\\ a_{m1}B & a_{m2}B & \\dots & a_{mn}B\\end{bmatrix}_{mp\\times nq}$$"
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"System composed of two qubits of state $|\\phi_1\\rangle, |\\phi_2\\rangle$ can be written as $|\\psi\\rangle = |\\phi_1\\rangle \\otimes |\\phi_2\\rangle$  \n",
"\n",
"Similarly, state of n-qubit system which is composed of n single qubits with states $|\\phi_1 \\rangle, |\\phi_2\\rangle, \\dots |\\phi_n \\rangle$ can be denoted as:\n",
"$$|\\psi \\rangle = |\\phi_1\\rangle \\otimes |\\phi_2\\rangle \\otimes \\dots \\otimes |\\phi_n\\rangle$$\n",
"\n",
"But we cannot always express an arbitrary n-qubit quantum system as a tensor product of n single qubit states, due to Quantum Entanglement"
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"## Quantum Entanglement\n",
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"A set of qubits whose combined state is $|\\psi \\rangle$ is said to be in a state of entanglement if $|\\psi \\rangle$ cannot be decomposed as $|\\psi \\rangle = |\\phi \\rangle \\otimes |\\xi \\rangle$ where $|\\phi \\rangle$ and $|\\xi \\rangle$ are two independent quantum states.\n",
"\n",
"In $|\\psi\\rangle = \\frac{1}{\\sqrt2}(|00\\rangle + |11\\rangle)$, $|\\psi\\rangle$ cannot be written as a tensor product of two single qubit states - they are in a state of entanglement.  \n",
"However, in the above, if we conduct a measurement of the first qubit, we obtain $|0\\rangle$ with a probability of $\\frac{1}{2}$ and $|1\\rangle$ with a probability of $\\frac{1}{2}$ (same situation if we measure the second qubit first).  \n",
"Suppose we have obtained $|0\\rangle$ on first qubit measurement $\\rightarrow$ we will obtain a measurement of $|0\\rangle$ with a probability of $1$ for the second qubit (as the state of the system has been collapsed to $|00\\rangle$). So from just measuring any one of the qubits, we can learn about the measurement outcome for the remaining qubit.\n",
"\n",
"Measurement of first qubit $\\rightarrow$ Probabilistic  \n",
"Measurement of subsequent second qubit $\\rightarrow$ Determined exactly\n"
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"### Bell States or EPR Pairs (Important Two-Qubit States):\n",
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"$$|\\Phi^+\\rangle = \\frac{1}{\\sqrt2}(|00\\rangle + |11\\rangle)$$\n",
"$$|\\Phi^-\\rangle = \\frac{1}{\\sqrt2}(|00\\rangle - |11\\rangle)$$\n",
"$$|\\Psi^+\\rangle = \\frac{1}{\\sqrt2}(|01\\rangle + |10\\rangle)$$\n",
"$$|\\Psi^-\\rangle = \\frac{1}{\\sqrt2}(|01\\rangle - |10\\rangle)$$\n",
"\n",
"### GHZ States (used in Quantum Error corrections):\n",
"$$|GHZ_\\pm \\rangle = \\frac{1}{\\sqrt2}(|000\\rangle \\pm |111\\rangle)$$"
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"## Multi-Qubit Gates\n",
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"### Controlled NOT Gate:  \n",
"Analogue to Classical XOR gate $\\rightarrow$ CNOT Gate (Controlled NOT Gate)  \n",
"CNOT Gate has two inputs: \"control\" qubit and \"target\" qubit  \n",
"If control qubit is set to $|1\\rangle$, then flip target qubit, else do nothing (CNOT basically implements X gate on target qubit if controlled qubit is in state $|1\\rangle$)\n",
"$$\\text{CNOT} := \\begin{bmatrix}1 & 0 & 0 & 0 \\\\ 0 & 1 & 0 & 0 \\\\ 0 & 0 & 0 & 1 \\\\ 0 & 0 & 1 & 0\\end{bmatrix}$$\n",
"\n",
"For $|\\psi \\rangle = \\alpha_0 |00\\rangle + \\alpha_1 |01\\rangle + \\alpha_2 |10\\rangle + \\alpha_3 |11\\rangle $, action of CNOT gate can be described as:\n",
"$$\\text{CNOT}|\\psi \\rangle = \\alpha_0 |00\\rangle + \\alpha_1 |01\\rangle + \\alpha_2 |11\\rangle + \\alpha_3 |10\\rangle $$  \n",
"We can state the action of the CNOT Gate in computational basis state of the individual qubits:\n",
"$$\\text{CNOT}|a\\rangle |b\\rangle \\rightarrow |a\\rangle |a \\oplus b\\rangle$$ \n",
"or, we can think of CNOT as a function that acts on two qubits:\n",
"$$\\text{CNOT}(|a\\rangle, |b\\rangle) \\rightarrow (|a\\rangle, |a \\oplus b\\rangle)$$\n",
"\n",
"$\\text{CNOT} + \\text{all single qubit quantum gates} \\rightarrow \\text{can be used to construct any quantum gate}$  \n",
"So, CNOT and all single qubit quantum gates are called universal quantum gates\n",
"\n",
"#### Controlled Hadamard Gate:\n",
"$$C_H = \\begin{bmatrix}1 & 0 & 0 & 0 \\\\ 0 & 1 & 0 & 0 \\\\[6pt] 0 & 0 & \\frac{1}{\\sqrt2} & \\frac{1}{\\sqrt2} \\\\[6pt] 0 & 0 & \\frac{1}{\\sqrt2} & -\\frac{1}{\\sqrt2}\\end{bmatrix}$$\n",
"\n",
"#### Toffoli Gate (CCNOT):\n",
"\n",
```

```
"Extension of CNOT to three qubits, first two are control qubits and the 3rd is target qubit. Target qubit is flipped iff both control qubits are set to 1\n",
"$$CCNOT |a \\rangle | b \\rangle |c\\rangle \\rightarrow |a\\rangle|b\\rangle|c \\oplus (a\\cdot b)\\rangle$$  \n",
"Corresponding unitary matrix for CCNOT gate (operating on 3 qubits, so $8 \\times 8$ matrix)\n",
"$$CCNOT := \\begin{bmatrix}1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\\\\n",
"                          0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\\\\n",
"                          0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\\\\n",
"                          0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\\\\n",
"                          0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\\\\n",
"                          0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\\\\n",
"                          0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\\\\n",
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"                            \\end{bmatrix}$$"
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"qc.cx(q[0], q[1])\n",
"qc.measure(q, c)\n",
"\n",
"qc.draw()"
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"         ?  ??????   \n",
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"With multiple qubits of state $|\\psi \\rangle$, we can get an estimate of $\\alpha, \\beta$ but not with a single qubit because on measuring, it collapses to either one of its computational basis states $|0\\rangle$, or $|1\\rangle$\n",
"\n",
"Question is, can we clone a qubit to make mutliple copies of $|\\psi\\rangle$? (Need a circuit that takes a qubit and an ancillary qubit [Ancilla] as input and output two copies of $|\\psi\\rangle$) $\\rightarrow$ CNOT gate might be useful (due to the following copying action):\n",
"\n",
"$$CNOT|0\\rangle |0\\rangle \\rightarrow |0\\rangle |0\\rangle$$\n",
"$$CNOT|1\\rangle |0\\rangle \\rightarrow |1\\rangle |1\\rangle$$\n",
"\n",
"But, for any given arbitary qubit state,\n",
"$$CNOT(\\alpha |0\\rangle + \\beta|1\\rangle)\\rightarrow \\alpha |0\\rangle|0\\rangle+\\beta|1\\rangle|1\\rangle \\text{(Entanglement!)}$$\n",
"We wanted:\n",
"$$|\\psi\\rangle \\otimes |\\psi\\rangle = (\\alpha |0\\rangle + \\beta|1\\rangle)\\otimes(\\alpha |0\\rangle + \\beta|1\\rangle)$$\n",
"\n",
"Infact, no such circuit for copying can exist, i.e., no Unitary U exists for all unknown arbitrary states $|\\psi\\rangle$, $U|\\psi\\rangle|j\\rangle \\rightarrow |\\psi\\rangle|\\psi\\rangle$"
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"\n",
"qc.h(q[0])\n",
"qc.cx(q[0], q[1])\n",
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"qc.measure(q, c)\n",
"qc.draw()\n"
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"$$Pr(i) = \\langle\\psi|M^{\\dagger}_i M_i |\\psi\\rangle$$\n",
"And on obtaining the outcome $i$, the ssytem collapses to:\n",
"$$|\\psi'\\rangle = \\frac{M_i|\\psi\\rangle}{\\sqrt{\\langle\\psi|M^{\\dagger}_i M_i |\\psi\\rangle}}$$ \n",
"(Post measurement state is normalized)\n",
"\n",
"For eg., Probability of obtaining outcome $00$ upon measuring $|\\psi\\rangle$ is:\n",
"$$Pr(00) = \\langle\\psi|(|00\\rangle\\langle 00|)^{\\dagger}(|00\\rangle\\langle 00|)|\\psi\\rangle$$\n",
"Let $|\\psi \\rangle = \\frac{1}{2}(|00\\rangle + |01\\rangle + |10\\rangle + |11\\rangle)$, so\n",
"\n",
"$$\\begin{align*}(|00\\rangle\\langle 00|)|\\psi\\rangle &= (|00\\rangle\\langle 00|)\\bigg[\\frac{1}{2}(|00\\rangle + |01\\rangle + |10\\rangle + |11\\rangle)\\bigg] \\\\\n",
"&=\\frac{1}{2}|00\\rangle \\bigg(\\langle 00|00\\rangle + \\langle 00|01\\rangle+\\langle 00|10\\rangle+\\langle 00|11\\rangle\\bigg) \\\\\n",
"&=\\frac{1}{2}|00\\rangle \\end{align*}$$\n",
"Now, \n",
"$$ \\langle\\psi|(|00\\rangle\\langle 00|)^{\\dagger} = \\bigg((|00\\rangle \\langle 00|)|\\psi\\rangle\\bigg)^{\\dagger}$$\n",
"$$\\implies Pr(00) = (\\frac{1}{2}\\langle 00|)(\\frac{1}{2}|00\\rangle) = \\frac{1}{4}\\langle 00 | 00\\rangle = \\frac{1}{4}$$\n",
"\n",
"On measuring just the of the first qubit of the state $|\\psi \\rangle$, the probability of obtaining outcome $0$ can be computed as $\\frac{1}{2}$, and post measurement, the state of the system on measuring the first qubit as $0$ can be given as \n",
```

```
"$$|\\psi_0\\rangle = \\frac{1}{\\sqrt2}(|00\\rangle + |01\\rangle)$$\n",
"\n",
"Set of measurement operators must satisfy $$\\sum_i M_i^{\\dagger}M_i = I \\\\\\text{(Completeness Relation)}$$\n",
"\n",
"Projective measurements: Set of operators $P_i = M_i^{\\dagger}M_i$ satisfying completeness relation $\\sum_iP_i=1$ as well as that the operators are orthogonal, so $P_iP_{i'}=P_i$ only when $i'=i$\n",
"\n",
"Example of projective measurement is the following set of operators:\n",
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File: 4_Quantum Teleportation.ipynb

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"from qiskit import *\n",
```

```
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"from math import *\n",
"import qiskit\n",
"\n",
"load_dotenv()\n",
"IBM_KEY = os.getenv(\"API_KEY\")\n",
"provider = IBMProvider()"
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"\n"
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"                       ?   ?    ?????????????????????????      ? \n",
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```

```
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"ca = ClassicalRegister(2)\n",
"cb = ClassicalRegister(1)\n",
"\n",
"qc = QuantumCircuit(q, ca, cb)\n",
"# Creating entaglement\n",
"qc.h(q[1])\n",
"qc.cx(q[1], q[2])\n",
"\n",
"# Creating a dummy state that is to be teleported\n",
"qc.h(q[0])\n",
"qc.cx(q[0], q[1])\n",
"qc.h(q[0])\n",
"qc.measure(q[0], ca[0])\n",
"qc.measure(q[1], ca[1])\n",
"qc.barrier()\n",
"\n",
"# Controlled on the o/p receieved by Bob, he performs X gate and Z gate\n",
"qc.x(q[2]).c_if(ca[1] ,1)\n",
"qc.z(q[2]).c_if(ca[0] ,1)\n",
"\n",
"# Check if state obtained is same as one to be teleported (H^{dag} = H), So output on
measuring q[2] should always be |0>\n",
"qc.h(q[2])\n",
"qc.measure(q[2], cb[0])\n",
"\n",
"qc.draw()"
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}
],
"source": [
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"qjob = execute(qc, backend)\n",
"counts = qjob.result().get_counts()\n",
```

```
"print(counts)\n",
"# Output structure is cb[0] ca[0]ca[1]\n",
"# Always get 0 for q[2] "
]
}
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"metadata": {
"kernelspec": {
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"language": "python",
"name": "python3"
},
"language_info": {
"codemirror_mode": {
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```

Repository: SnapScribe

File: Backend_resources.md

```
# Backend Development Resources
This file contains a comprehensive list of resources that can be valuable for backend development in the SnapScribe project. These resources cover various aspects such as backend frameworks and API development.

## Backend Frameworks
For both of the suggested frameworks, basic familiarity with Python is necessary.
- [Flask](https://flask.palletsprojects.com/en/2.3.x/) - A lightweight and versatile Python web framework. Flask provides a simple yet powerful foundation for building web applications and APIs.

- [CS50 2020 lec 9 - Flask](https://youtu.be/x_c8pTW8ZUc) - Great tutorial for building a Flask web app. Holds your hand all the way through and explains all the basic concepts. Probably all the Flask you need to learn for this project. But remember that they use Jinja syntax which we won't be using or needing, it is old. We will need to connect it to a React frontend.

- [Django](https://docs.djangoproject.com/en/4.2/) - A high-level Python web framework known for its "batteries included" approach. It offers robust features for building scalable and secure web applications.

The preferred method for this project is a Flask web server serving the ML model, but you can use Django if you're more comfortable with that. The high level concept remains the same with any of the two, which is that you will have to build routes in the web app to serve predictions.

## HTTP Basics

- [CS50 2020 Lec 8 - Web](https://youtu.be/5g0x2xv3aHU) - Great introduction to HTTP protocols and type of requests like GET and POST, their differences and when each one is used. Also gives an intro as to what headers are. Great starting point.

- [HTTP MDN Docs](https://developer.mozilla.org/en-US/docs/Web/HTTP) - Very in-depth. Do not need to learn all of this. Don't even try to remember or read through this whole thing. Use as and when needed as reference material.

- [HTTP Headers MDN Docs](https://developer.mozilla.org/en-US/docs/Web/HTTP/Headers) - Same as above, use as reference material.

## Sending Requests and Fetching Responses

- [Requests in Python](https://docs.python-requests.org/en/latest/) - Requests is an elegant and simple HTTP library for Python. You might need to use this.

For sending and fetching requests in React, you'll need the following (basically the following will communicate between the frontend and backend - user uploads image to the frontend, that is sent to the backend and the backend responds with a caption that is then displayed by the frontend).
```

- [Form Handling - Net Ninja](https://www.youtube.com/playlist?list=PL4cUxeGkcC9gZD-Tvwfod2gaISzfRiP9d) - Videos #14-32 are essential. Won't take long. Definitely watch them.

- [Axios](https://axios-http.com/docs/intro) - A popular JavaScript library for making HTTP requests from web browsers or Node.js. Axios is great for the handling of responses that it provides.

- [Axios freeCodeCamp Tutorial](https://www.freecodecamp.org/news/how-to-use-axios-with-react/) - Guide to get started with Axios and React.

- [Fetch API MDN Docs](https://developer.mozilla.org/en-US/docs/Web/API/Fetch_API) - The MDN Web Docs guide to the Fetch API, a modern browser feature for making asynchronous HTTP requests.

- [Asynchronous JavaScript](https://www.freecodecamp.org/news/asynchronous-javascript) - Lean about Promises, Callbacks, and asynchronous code handling in JavaScript. You will be able to apply this in React after that.

API Resources
Learn about APIs, their types. Specifically the REST API design is very useful. Learn that by Googling. You will be building the API with Flask. But getting some theory in your head won't hurt, but don't spend much time on this.

[Postman](https://www.postman.com/) - Good tool for testing API routes with various types of input. You can learn how to use this for API testing by Googling and YouTube.

File: CODE_OF_CONDUCT.md

SnapScribe Code of Conduct for CSOC
Introduction
SnapScribe is committed to creating an open and inclusive community where everyone feels welcome, respected, and valued. We expect all community members, including contributors, maintainers, and users, to adhere to this Code of Conduct when participating in any SnapScribe-related activities or contributing to the project. This Code of Conduct outlines our shared values and the behavior we expect from individuals within our community.

Our Values
- Respect: Treat others with respect, kindness, and empathy. Be considerate of different perspectives and experiences.
- Inclusivity: Foster an inclusive and diverse environment where everyone feels safe and valued, regardless of their race, ethnicity, gender, sexual orientation, age, ability, or any other personal attribute.
- Collaboration: Encourage collaboration and constructive communication. Work together to achieve common goals and resolve conflicts in a respectful manner.
- Openness: Embrace openness, transparency, and accountability in our interactions and decision-making processes.
- Professionalism: Maintain a professional and courteous demeanor. Refrain from engaging in any form of harassment, discrimination, or disruptive behavior.
Expected Behavior
All community members are expected to:

- Be respectful and considerate of others' opinions, ideas, and experiences.
- Use inclusive language and avoid any offensive, discriminatory, or derogatory remarks or behavior.
- Be open to constructive feedback and provide feedback in a respectful and constructive manner.
- Exercise empathy and assume good intentions in all interactions.
- Be mindful of the impact of your words and actions on others in the community.
- Respect the privacy and confidentiality of others.
- Be accountable for your actions and their consequences.

Unacceptable Behavior

The following behaviors are considered unacceptable within the SnapScribe community:

- Harassment, bullying, or intimidation in any form.
- Discrimination or offensive comments related to race, ethnicity, gender, sexual orientation, age, ability, or any other personal attribute.
- Use of derogatory, offensive, or inappropriate language or imagery.
- Personal attacks, insults, or trolling.
- Disruptive or disrespectful behavior during community discussions or events.
- Any other behavior that violates the principles outlined in this Code of Conduct.

File: CONTRIBUTE.md

Contributing to SnapScribe

Thank you for your interest in contributing to SnapScribe! We appreciate your support in making this project even better. Before contributing, take a look at the following guidelines, which will help you get started with making your first PRs and resolving issues!

How to Contribute

1. Fork the repository to your GitHub account.
2. Create a new branch from the main branch for your contributions.
3. Make your changes and improvements in the branch you created.
4. Ensure your code adheres to the project's coding style and follows best practices.
5. Test your changes locally to ensure they function as expected.
6. Commit your changes with descriptive commit messages.
7. Push your branch to your forked repository.
8. Open a pull request (PR) from your branch to the main branch of the main repository.
9. Provide a clear and detailed description of the changes you made in the PR.
10. Be responsive to any feedback or comments provided during the review process.

Making Your First Pull Request (PR)

1. Find an issue labeled as "good first issue" among list of issues. These are great starting points.

2. Comment on the issue to let others know that you're interested in working on it. This helps prevent duplicate efforts and allows for coordination if multiple contributors are interested in the same issue.

3. Fork the repository to your GitHub account by clicking the "Fork" button on the top-right corner of the repository page.

4. Clone your forked repository to your local machine using the following command:

`git clone https://github.com/your-username/SnapScribe.git`

5. Create a new branch for your changes using a descriptive branch name:

`git checkout -b my-first-contribution`

6. Make the necessary changes and improvements to the codebase.

7. Test your changes locally to ensure they work as expected.

8. Commit your changes with a clear and concise commit message:
`git commit -m "Add feature XYZ"`

9. Push your changes to your forked repository:

`git push origin my-first-contribution`

10. Visit the original repository on GitHub and click the "New pull request" button.

11. Provide a descriptive title and detailed description for your pull request, explaining the changes you made.

12. Submit the pull request and wait for the project maintainers to review your changes. Be patient and responsive to any feedback or suggestions provided.

Code Style and Guidelines
- Follow the coding style and conventions used in the existing codebase.
- Write clear and concise code with meaningful variable and function names.
- Include comments in your code where necessary to enhance readability.
- Ensure your code is well-documented, including inline comments and docstrings.
- Write unit tests for new features or modifications to existing functionality.
- Run existing tests to ensure you haven't introduced any regressions.
Reporting Issues
- If you encounter any bugs, issues, or have suggestions for improvements, please submit an issue on the GitHub repository. When submitting an issue, please include the following information:

1. A clear and descriptive title.
2. A detailed description of the issue or suggestion.
3. Steps to reproduce the issue, if applicable.
4. Any relevant logs, error messages, or screenshots.

Documentation
Improvements to the project's documentation are highly valuable. If you find any gaps or areas that need clarification, please feel free to submit documentation updates or create new documentation where needed.

Collaboration and Communication
We encourage collaboration and open communication among contributors. If you have any questions or need assistance, please use the CSOC Discord Server's relevant channel. You can also reach out through GitHub discussions or comments on the relevant PR or issue.

File: Deployment_resources.md

Deployment Resources
This file provides a collection of resources for deploying the SnapScribe web application. Below are various options and guides for deploying your project on different platforms.

GitHub Pages
- [GitHub Pages](https://pages.github.com/) - Official documentation for deploying static websites directly from your GitHub repository to GitHub Pages. It provides step-by-step instructions to set up and configure your deployment.

- [Deploying a React App to GitHub Pages](https://create-react-app.dev/docs/deployment/#github-pages) - A guide that demonstrates how to deploy a React application to GitHub Pages using the gh-pages package and the npm run deploy command.

Netlify
- [Netlify](https://docs.netlify.com/) - A popular platform for deploying static websites, providing features like continuous deployment, custom domain support, and built-in CDN. Their official documentation provides detailed instructions on setting up and deploying your project.

- [Deploying a React App to Netlify](https://create-react-app.dev/docs/deployment/#netlify) - A step-by-step guide on deploying a React application to Netlify. It covers configuring build settings, setting up environment variables, and connecting your repository.

PythonAnywhere
- [PythonAnywhere](https://www.pythonanywhere.com/) - A cloud-based Python hosting service that allows you to deploy and run web applications. Their official documentation provides instructions for deploying Python web apps and configuring the necessary settings.

- [Deploying a Flask App on PythonAnywhere](https://help.pythonanywhere.com/pages/Flask/) - A detailed tutorial on deploying a Flask application on PythonAnywhere. It covers setting up the virtual environment, configuring the web server, and deploying the application.

File: Frontend_resources.md

Frontend Development Resources
The frontend for SnapScribe is meant to be a React.js web app styles with Tailwind CSS. For this part of the project, the most useful resource will probably be the documentations of the respective frameworks, along with a few YouTube guides here and there. The Art of Googling is *ESSENTIAL* for this part of the project specially. StackOverflow, YouTube, Reddit are your best friends.

First you will have to come up with a rough overview of a design for the website. What

kind of components are necessary, what pages will contain what, although a brief guideline for that will be provided soon. Styling will be totally upto the contributors.

Design and UI Inspiration
- [Dribbble](https://dribbble.com/) - An online community of designers showcasing their work. Explore the platform for UI/UX inspiration, trends, and design ideas.
- [Behance](https://www.behance.net/) - Discover creative projects and portfolios from designers around the world. Explore different design styles and layouts.

Frontend Frameworks and Libraries
- [React.js](https://react.dev/learn) - A popular JavaScript library for building user interfaces. It offers a component-based approach and efficient rendering for creating interactive UIs.

- [Tailwind CSS](https://tailwindcss.com/docs/installation) - A utility-first CSS framework that allows you to rapidly build custom user interfaces. It provides a set of pre-defined CSS classes to streamline styling.

- [React Router](https://reactrouter.com/en/main) - For creating multi-page web apps in React.

Tutorials, YouTube Playlists
- FreeCodeCamp - An online learning platform with interactive tutorials and projects for frontend development. It covers HTML, CSS, JavaScript, and popular frontend frameworks. Look at their website as well as YouTube channel for guided tutorials

- Codecademy - Good place for learning Javascript, JSX and start with React.js. Before learning React.js, you must be comfortable with the basics of Javascript and JSX.

- [Javascript Mastery](https://www.youtube.com/@javascriptmastery) - Great guided projects and will get you up and running with React very quick! Highly recommended. They describe a great project structure at the beginning of every video which would help to keep modularity of React.

- [Net Ninja](https://www.youtube.com/@NetNinja) - Great playlists on more technical aspects of React like Form handling, submission handling, etc.

- [React Tutorial by Net Ninja](https://www.youtube.com/playlist?list=PL4cUxeGkcC9gZD-Tvwfod2gaISzfRiP9d) - The definitive playlist for Form handling and explanation of a lot of parts in bite sized quick videos.

- [React Router Example](https://youtu.be/xMNhDf5-hvk) - Example of how to create a multi page web app if you need it.

UI Component Libraries
- [Material-UI](https://mui.com/material-ui/getting-started/overview/) - A popular React component library that follows Google's Material Design guidelines. It provides a wide range of pre-built UI components and styles.

- [Chakra UI](https://chakra-ui.com/getting-started) - A simple and customizable UI component library for React. It focuses on accessibility, developer experience, and easy theming.