

# 1)

## SPECTRE: SPECTROGRAM BASED MUSIC RECOMMENDER

- **WHAT**

A SONG RECOMMENDER TO LET ME LISTEN TO MY MUSIC ON THE STEREO, BUT ONLY PLAYING SONGS THAT DO NOT UPSET MY FAMILY



- **WHY**

EXISTING RECOMMENDER SYSTEMS ARE BASED ON META DATA AND PROFILE MATCHING BETWEEN PERSONS. THIS IS TOO COARSE-GRAINED FOR MY PURPOSES. I WANT TO BUILD A SYSTEM TO RECOMMEND SONGS BASED ON THEIR SOUND CHARACTERISTICS

- **HOW**

TRANSFORM MP3 FILES INTO SPECTROGRAMS TO TRAIN A CONVOLUTIONAL NEURAL NETWORK

## 2) LABELLING THE DATA

MY WIFE NEEDS TO LABEL MY TRAINING DATA. FOR THAT PURPOSE, A PROGRAM PLAYS RANDOM SONGS FROM POSITION 60S FOR MAX 30S. SHE CAN PRESS <Y> OR <N> ANY TIME TO CONTINUE TO THE NEXT SONG.  
SHE WAS ABLE TO LABEL 1000 SONGS WITHIN 40 MINUTES!

MP3 COLLECTION, ~ 10K SONGS



PLAY RANDOM SONGS

```
(dl course) > python categorize.py
Number of rated files y/n: 0/0
/mp3/Gary Moore/Gary Moore - Live At Montreux (Disc 1)/02 - Midnight Blues.mp3
y/n/s/x:
Number of rated files y/n: 0/1
/mp3/J. S. Bach/J. S. Bach - Motetten/01 - Singet dem Herrn ein neues Lied, BWV 225.mp3
y/n/s/x:
Number of rated files y/n: 0/2
/mp3/Prince/Prince - Crystal Ball - CD2/08 - cloreen Bacon Skin.mp3
y/n/s/x:
Number of rated files y/n: 0/3
/mp3/Red Hot Chili Peppers/Red Hot Chili Peppers - The Uplift Mofo Party Plan/10 - Walkin' On Down The Road.mp3
y/n/s/x:
Number of rated files y/n: 0/4
/mp3/Giorgia/Giorgia - Mtv Unplugged/09 - Vivi davvero.mp3
y/n/s/x:
Number of rated files y/n: 1/4
/mp3/Free/Free - Fire And Water/06 - Don't Say Yoy Love Me.mp3
y/n/s/x:
Number of rated files y/n: 2/4
/mp3/The Rolling Stones/The Rolling Stones - Goats Head Soup (Virgin re
y/n/s/x:
Number of rated files y/n: 3/4
/mp3/Jovanotti/Jovanotti - Oh, Vital/13 - Affermativo.mp3
y/n/s/x:
Number of rated files y/n: 4/4
/mp3/Prince/Prince - Days Of Montreux - CD4/10. FixUrLifeUP.mp3
y/n/s/x:
Number of rated files y/n: 4/5

```



VOTE !

~1000 SAMPLES FOR SUPERVISED LEARNING

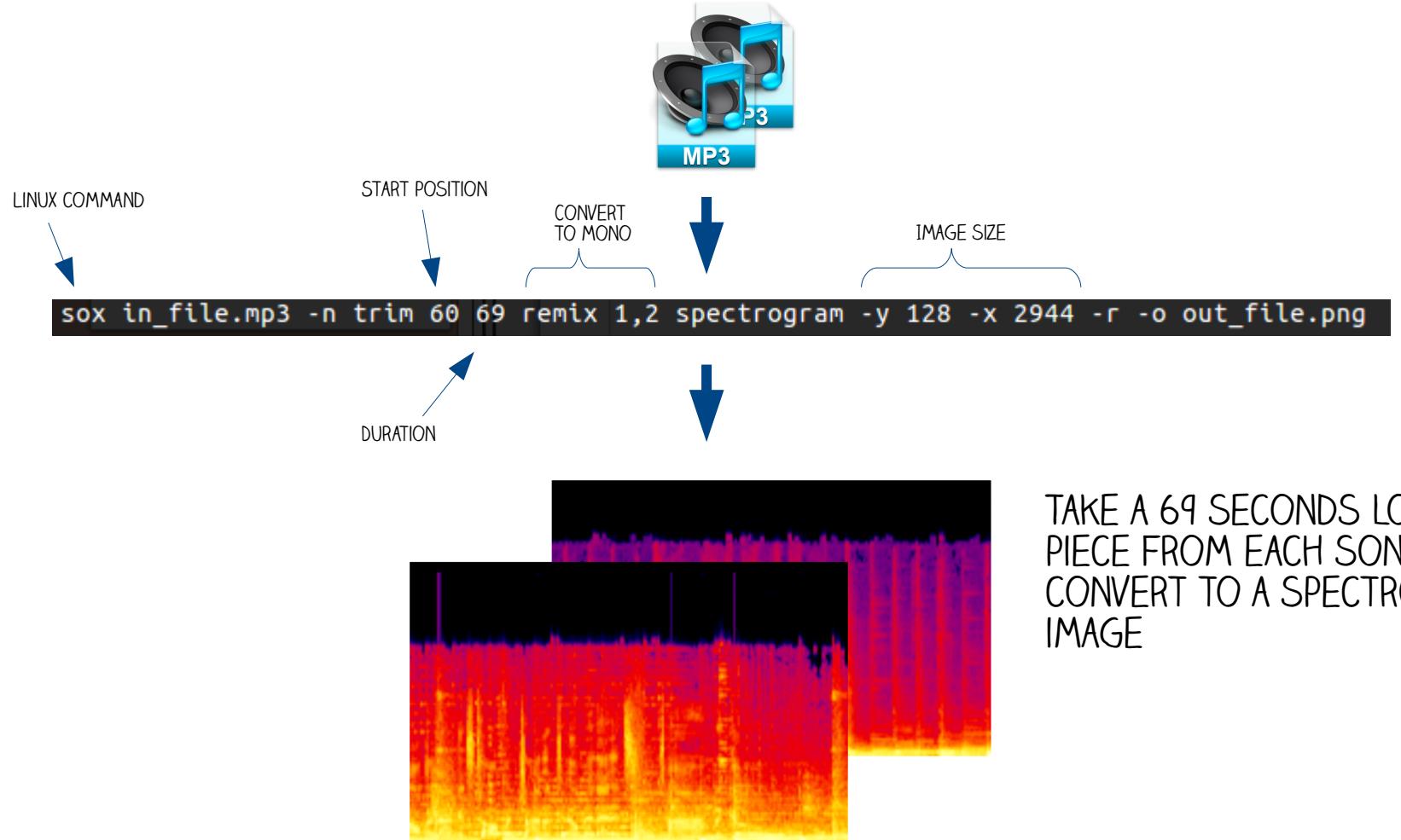


~500 SONGS

~500 SONGS

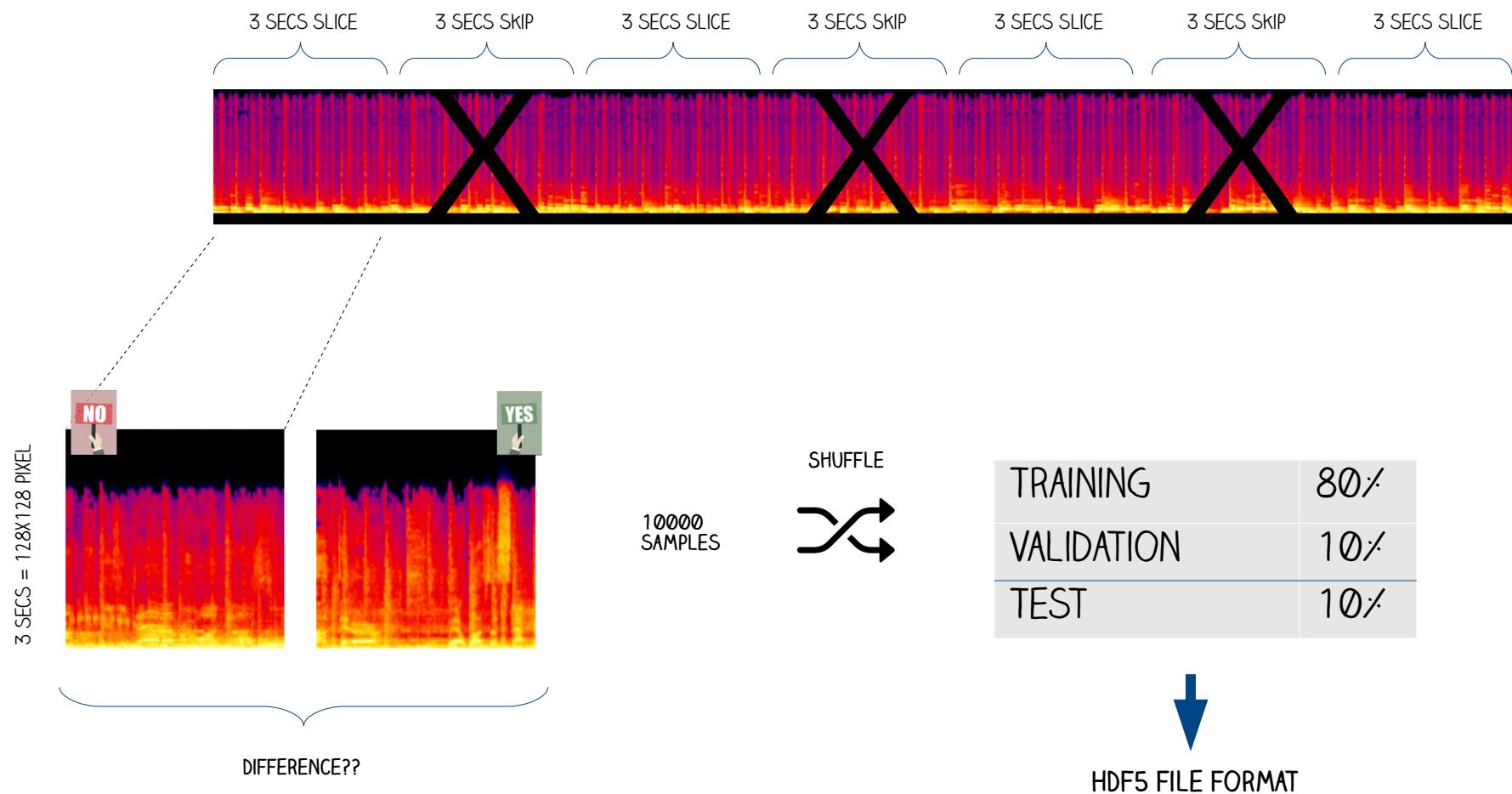
| A   | D |
|---|---|
| 1 /mp3/Prince/Prince - Rock This Joint - CD 2/05 - Release Yourself (incl. Hypno Paradise).mp3                              | n |
| 2 /mp3/The Stooges/The Stooges - The Weirdness/05 - The Weirdness.mp3   | n |
| 3 /mp3/Prince/Prince/Vault/1976/Sweet Thing.mp3   | n |
| 4 /mp3/Walls Bird/Walls Bird - The Mistakes Are Intentional/06 - Who's Listening Now.mp3                                    | y |
| 5 /mp3/Stiller Has/Stiller Has - Geisterbahn/10 - Sunnebrille.mp3   | y |
| 6 /mp3/Madonna/Madonna - Ray Of Light/07 - Madonna - Sky Fits Heaven.mp3  | n |
| 7 /mp3/Boy George/Boy George - Sold/10 - We've Got The Right.mp3  | n |
| 8 /mp3/Iggy Pop/Iggy Pop - A Million In Prizes - The Anthology - CD1/13 - Funtime.mp3                                       | n |
| 9 /mp3/The Brand New Heavies/The Brand New Heavies - Trunk Funk The Best Of The Brand New Heavies/05 - Dream On Dreamer.mp3 | y |
| 10 /mp3/Gorillaz/Gorillaz - Gorillaz/13 - Starslime.mp3   | y |
| 11 /mp3/Prince/The Slaughterhouse/06-Props_N_Pounds.mp3   | y |
| 12 /mp3/Prince/Prince/Vault/1982/Something In The Water (Does Not Com 1.mp3   | n |
| 13 /mp3/Iggy Pop/Iggy Pop - A Million In Prizes - The Anthology - CD1/11 - Kill City.mp3                                    | n |
| 14 /mp3/SOS - SOS/06 - SOS - Don't say Shit (P Chréten).mp3   | n |
| 15 /mp3/Various - Putumayo Presents Paris/05 - Je restai au lit.mp3   | y |

### 3) DATA PREPARATION



## 4) AUGMENTATION

SPLIT EACH IMAGE FROM 3) INTO MULTIPLE SAMPLES TO HAVE MORE TRAINING DATA AVAILABLE



## 5) AUTOMATED EVALUATION OF NETWORKS

NUMBER OF FILTERS      DROPOUT      MAX. POOLING

```
layers = []
layers += [[16], [0], [0]]
layers += [[0,16], [0], [1]]
layers += [[0,16], [0], [0]]
layers += [[0,16,32], [0], [1]]
layers += [[0,16,32], [0], [0]]
layers += [[0,16,32], [0], [1]]
layers += [[0,16,64], [0], [0]]
layers += [[0,16,64], [0], [1]]
layers += [[0,16,64], [0], [0]]
layers += [[0,16,64], [0], [1]]
layers += [[400], [0.5], [0]]
```

- DEFINITION OF 10 CONVOLUTIONAL LAYERS IN SCRIPT
- EACH LAYER WITH VARYING NUMBER OF FILTERS
- BRUTE FORCE SEARCH FOR BEST CONFIGURATION
- SELECTION BY MAX ACCURACY (RESULTS WRITTEN TO LOGFILE)

```
def add_c_layer(model, filter_param, dropout_param,max_pool_param):
    if filter_param > 0:
        model.add(Convolution2D(filter_param, kernel_size, input_shape=my_input_shape, padding='same'))
        model.add(BatchNormalization())
        model.add(Activation('relu'))
    if max_pool_param > 0:
        model.add(MaxPooling2D(pool_size=pool_size))
    if dropout_param > 0:
        model.add(Dropout(dropout_param))
```

### EarlyStopping

[source]

```
keras.callbacks.EarlyStopping(monitor='val_loss', min_delta=0, patience=0, verbose=0, mode='auto')
```

Stop training when a monitored quantity has stopped improving.

#### Arguments

- **monitor**: quantity to be monitored.
- **min\_delta**: minimum change in the monitored quantity to qualify as an improvement, i.e. an absolute change of less than `min_delta`, will count as no improvement.
- **patience**: number of epochs with no improvement after which training will be stopped.
- **verbose**: verbosity mode.
- **mode**: one of {auto, min, max}. In `min` mode, training will stop when the quantity monitored has stopped decreasing; in `max` mode it will stop when the quantity monitored has stopped increasing; in `auto` mode, the direction is automatically inferred from the name of the monitored quantity.

STOP  
EVALUATION  
WHEN  
NO PROGRESS  
FOR THREE  
EPOCHS

## 6) NETWORK SELECTION

STEP 1: FIND NETWORK WITH MAX ACCURACY FROM LOGGED RESULTS

MAX ACCURACY

```
2018-04-02 17:12:15 INFO For parameters 16.00 0.00 0.00 32.00 0.00 1.00 32.00 0.00 0.00 0.00 64.00 0.00 0.00 64.00 0.00 1.00 16.00 0.00 1.00 400.00 0.50 0.00, found MAX val_acc: 0.66 with # params 17216
2018-04-02 17:17:32 INFO For parameters 16.00 0.00 0.00 32.00 0.00 1.00 32.00 0.00 0.00 0.00 64.00 0.00 0.00 64.00 0.00 1.00 64.00 0.00 0.00 16.00 0.00 1.00 400.00 0.50 0.00, found MAX val_acc: 0.68 with # p
2018-04-02 17:20:54 INFO For parameters 16.00 0.00 0.00 32.00 0.00 1.00 32.00 0.00 0.00 0.00 32.00 0.00 1.00 16.00 0.00 1.00 400.00 0.50 0.00, found MAX val_acc: 0.67 with # params 1669922
2018-04-02 17:25:00 INFO For parameters 16.00 0.00 0.00 32.00 0.00 1.00 32.00 0.00 0.00 0.00 32.00 0.00 1.00 64.00 0.00 0.00 16.00 0.00 1.00 400.00 0.50 0.00, found MAX val_acc: 0.65 with # params 16932
2018-04-02 17:28:27 INFO For parameters 16.00 0.00 0.00 32.00 0.00 1.00 32.00 0.00 0.00 0.00 32.00 0.00 1.00 64.00 0.00 0.00 16.00 0.00 1.00 400.00 0.50 0.00, found MAX val_acc: 0.69 with # params 464
2018-04-02 17:32:30 INFO For parameters 16.00 0.00 0.00 32.00 0.00 1.00 32.00 0.00 0.00 0.00 32.00 0.00 1.00 64.00 0.00 0.00 16.00 0.00 1.00 400.00 0.50 0.00, found MAX val_acc: 0.68 with # p
2018-04-02 17:36:12 INFO For parameters 16.00 0.00 0.00 32.00 0.00 1.00 32.00 0.00 0.00 0.00 32.00 0.00 1.00 64.00 0.00 0.00 16.00 0.00 1.00 400.00 0.50 0.00, found MAX val_acc: 0.64 with # p
2018-04-02 17:40:29 INFO For parameters 16.00 0.00 0.00 32.00 0.00 1.00 32.00 0.00 0.00 0.00 32.00 0.00 1.00 64.00 0.00 0.00 16.00 0.00 1.00 400.00 0.50 0.00, found MAX val_acc: 0.67 with # p
2018-04-02 17:43:51 INFO For parameters 16.00 0.00 0.00 32.00 0.00 1.00 32.00 0.00 0.00 0.00 32.00 0.00 1.00 64.00 0.00 0.00 16.00 0.00 1.00 400.00 0.50 0.00, found MAX val_acc: 0.66 with # p
2018-04-02 17:47:52 INFO For parameters 16.00 0.00 0.00 16.00 0.00 0.00 32.00 0.00 1.00 64.00 0.00 1.00 16.00 0.00 1.00 400.00 0.50 0.00, found MAX val_acc: 0.68 with # params 1676914
2018-04-02 17:52:07 INFO For parameters 16.00 0.00 0.00 16.00 0.00 0.00 32.00 0.00 1.00 64.00 0.00 1.00 64.00 0.00 0.00 16.00 0.00 1.00 400.00 0.50 0.00, found MAX val_acc: 0.69 with # params 17146
2018-04-02 17:59:10 INFO For parameters 16.00 0.00 0.00 16.00 0.00 0.00 32.00 0.00 1.00 64.00 0.00 0.00 64.00 0.00 0.00 1.00 16.00 0.00 1.00 400.00 0.50 0.00, found MAX val_acc: 0.71 with # params 17146
2018-04-02 18:04:09 INFO For parameters 16.00 0.00 0.00 16.00 0.00 0.00 32.00 0.00 1.00 64.00 0.00 0.00 64.00 0.00 1.00 16.00 0.00 1.00 400.00 0.50 0.00, found MAX val_acc: 0.69 with # p
2018-04-02 18:10:03 INFO For parameters 16.00 0.00 0.00 16.00 0.00 0.00 32.00 0.00 1.00 32.00 0.00 1.00 16.00 0.00 1.00 400.00 0.50 0.00, found MAX val_acc: 0.65 with # params 1662930
2018-04-02 18:13:55 INFO For parameters 16.00 0.00 0.00 16.00 0.00 0.00 32.00 0.00 1.00 32.00 0.00 1.00 64.00 0.00 0.00 16.00 0.00 1.00 400.00 0.50 0.00, found MAX val_acc: 0.69 with # params 16862
2018-04-02 18:20:14 INFO For parameters 16.00 0.00 0.00 16.00 0.00 0.00 32.00 0.00 1.00 32.00 0.00 1.00 64.00 0.00 1.00 16.00 0.00 1.00 400.00 0.50 0.00, found MAX val_acc: 0.71 with # params 4574
2018-04-02 18:25:43 INFO For parameters 16.00 0.00 0.00 16.00 0.00 0.00 32.00 0.00 1.00 32.00 0.00 1.00 64.00 0.00 0.00 16.00 0.00 1.00 400.00 0.50 0.00, found MAX val_acc: 0.70 with # p
2018-04-02 18:28:47 INFO For parameters 16.00 0.00 0.00 16.00 0.00 0.00 32.00 0.00 1.00 32.00 0.00 1.00 64.00 0.00 0.00 16.00 0.00 1.00 400.00 0.50 0.00, found MAX val_acc: 0.68 with # p
2018-04-02 18:34:53 INFO For parameters 16.00 0.00 0.00 16.00 0.00 0.00 32.00 0.00 1.00 32.00 0.00 1.00 64.00 0.00 0.00 64.00 0.00 1.00 16.00 0.00 1.00 400.00 0.50 0.00, found MAX val_acc: 0.71 with # p
2018-04-02 18:39:38 INFO For parameters 16.00 0.00 0.00 16.00 0.00 0.00 32.00 0.00 1.00 32.00 0.00 1.00 64.00 0.00 0.00 64.00 0.00 1.00 64.00 0.00 0.00 16.00 0.00 1.00 400.00 0.50 0.00, found MAX val_acc: 0.64 with # params 16862
2018-04-02 18:43:54 INFO For parameters 16.00 0.00 0.00 16.00 0.00 0.00 32.00 0.00 1.00 32.00 0.00 0.00 64.00 0.00 1.00 16.00 0.00 1.00 400.00 0.50 0.00, found MAX val_acc: 0.68 with # p
2018-04-02 18:48:08 INFO For parameters 16.00 0.00 0.00 16.00 0.00 0.00 32.00 0.00 1.00 32.00 0.00 0.00 64.00 0.00 1.00 64.00 0.00 0.00 16.00 0.00 1.00 400.00 0.50 0.00, found MAX val_acc: 0.66 with # p
```

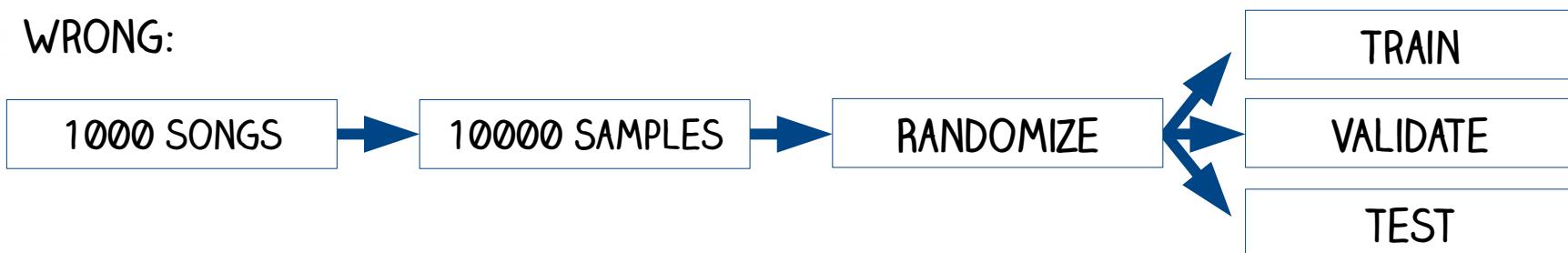
STEP 2: TRIAL-AND-ERROR FINE TUNING OF THOSE NETWORKS

## 7) LESSONS LEARNED: BE CAREFUL WITH DATA SEPARATION!

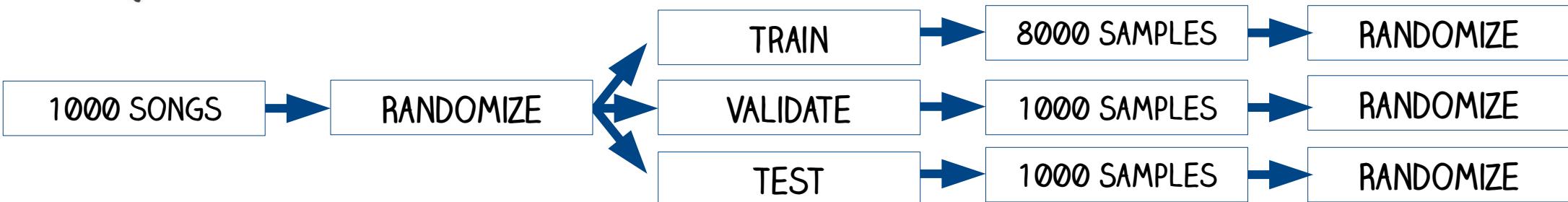
→ ACCURACY OF 73% IN THE FIRST TRIES. THIS VALUE IS SUSPICIOUSLY HIGH

→ I HAD THE SAME (WELL, VERY SIMILAR) DATA IN THE TRAINING AND THE VALIDATION SETS

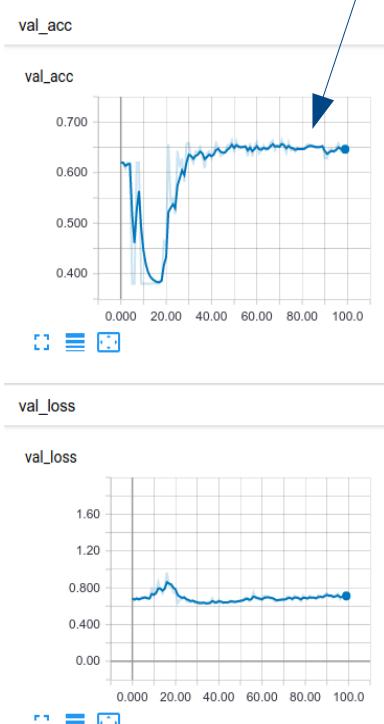
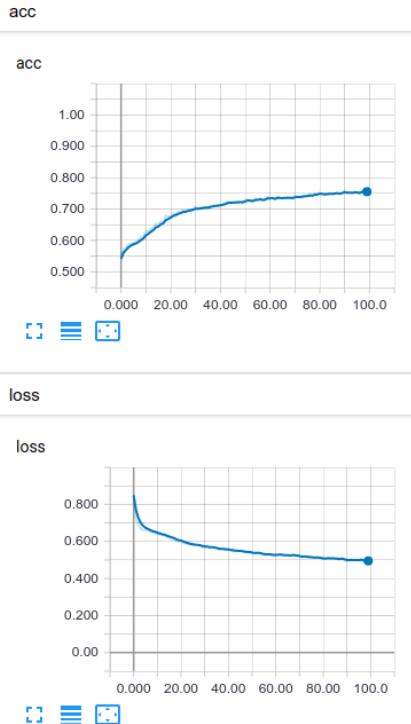
 WRONG:



 CORRECT:



AND TRY AGAIN...



MAX. ~ 0.65

| Layer (type)                                | Output Shape         | Param # |
|---|----------------------|---------|
| conv2d_1 (Conv2D)                           | (None, 128, 128, 16) | 448     |
| batch_normalization_1 (Batch Normalization) | (None, 128, 128, 16) | 64      |
| activation_1 (Activation)                   | (None, 128, 128, 16) | 0       |
| dropout_1 (Dropout)                         | (None, 128, 128, 16) | 0       |
| conv2d_2 (Conv2D)                           | (None, 128, 128, 16) | 2320    |
| batch_normalization_2 (Batch Normalization) | (None, 128, 128, 16) | 64      |
| activation_2 (Activation)                   | (None, 128, 128, 16) | 0       |
| max_pooling2d_1 (MaxPooling2D)              | (None, 64, 64, 16)   | 0       |
| dropout_2 (Dropout)                         | (None, 64, 64, 16)   | 0       |
| conv2d_3 (Conv2D)                           | (None, 64, 64, 16)   | 2320    |
| batch_normalization_3 (Batch Normalization) | (None, 64, 64, 16)   | 64      |
| activation_3 (Activation)                   | (None, 64, 64, 16)   | 0       |
| dropout_3 (Dropout)                         | (None, 64, 64, 16)   | 0       |
| conv2d_4 (Conv2D)                           | (None, 64, 64, 16)   | 2320    |
| batch_normalization_4 (Batch Normalization) | (None, 64, 64, 16)   | 64      |
| activation_4 (Activation)                   | (None, 64, 64, 16)   | 0       |
| max_pooling2d_2 (MaxPooling2D)              | (None, 32, 32, 16)   | 0       |
| dropout_4 (Dropout)                         | (None, 32, 32, 16)   | 0       |
| conv2d_5 (Conv2D)                           | (None, 32, 32, 16)   | 2320    |
| batch_normalization_5 (Batch Normalization) | (None, 32, 32, 16)   | 64      |
| activation_5 (Activation)                   | (None, 32, 32, 16)   | 0       |
| dropout_5 (Dropout)                         | (None, 32, 32, 16)   | 0       |
| conv2d_6 (Conv2D)                           | (None, 32, 32, 16)   | 2320    |
| batch_normalization_6 (Batch Normalization) | (None, 32, 32, 16)   | 64      |
| activation_6 (Activation)                   | (None, 32, 32, 16)   | 0       |
| max_pooling2d_3 (MaxPooling2D)              | (None, 16, 16, 16)   | 0       |
| dropout_6 (Dropout)                         | (None, 16, 16, 16)   | 0       |
| conv2d_7 (Conv2D)                           | (None, 16, 16, 16)   | 2320    |
| batch_normalization_7 (Batch Normalization) | (None, 16, 16, 16)   | 64      |
| activation_7 (Activation)                   | (None, 16, 16, 16)   | 0       |
| dropout_7 (Dropout)                         | (None, 16, 16, 16)   | 0       |
| conv2d_8 (Conv2D)                           | (None, 16, 16, 16)   | 2320    |
| batch_normalization_8 (Batch Normalization) | (None, 16, 16, 16)   | 64      |
| activation_8 (Activation)                   | (None, 16, 16, 16)   | 0       |
| max_pooling2d_4 (MaxPooling2D)              | (None, 8, 8, 16)     | 0       |
| dropout_8 (Dropout)                         | (None, 8, 8, 16)     | 0       |
| flatten_1 (Flatten)                         | (None, 1024)         | 0       |
| dense_1 (Dense)                             | (None, 400)          | 410000  |
| batch_normalization_9 (Batch Normalization) | (None, 400)          | 1600    |
| activation_9 (Activation)                   | (None, 400)          | 0       |
| dropout_9 (Dropout)                         | (None, 400)          | 0       |
| dense_2 (Dense)                             | (None, 2)            | 802     |
| activation_10 (Activation)                  | (None, 2)            | 0       |

=====  
Total params: 429,602  
Trainable params: 428,546  
Non-trainable params: 1,056

FINAL EVALUATION ON TEST DATA SET: 1230 SAMPLES, ACCURACY=0.69!