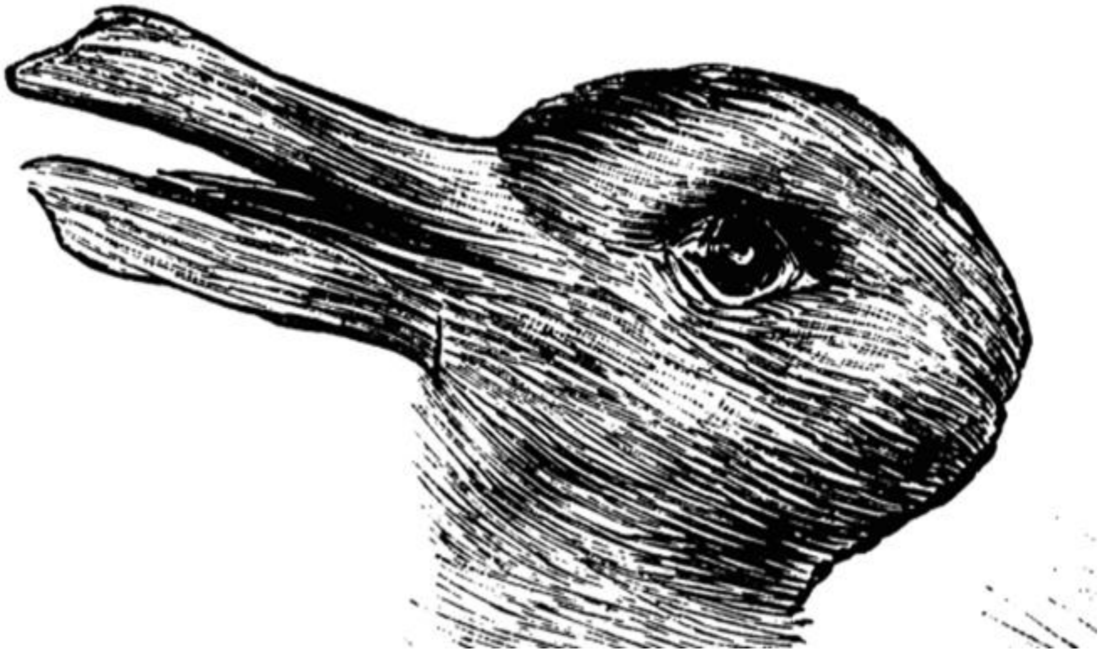
Using Deep Learning to Estimate Multiple Song Tempos

THIS IS A DUCK
(facing left)

THIS IS ALSO A RABBIT
(facing right)



ONE SONG CAN HAVE MORE THAN ONE TEMPO

EVEN IF THE TEMPO DOESN'T CHANGE DURING THE SONG

Jackson 5

"I Want You Back"

100 Beats per Minute 🎵

Good for typical walking pace

Jackson 5

"I Want You Back"

200 Beats per Minute 🎶

Good for brisk running pace

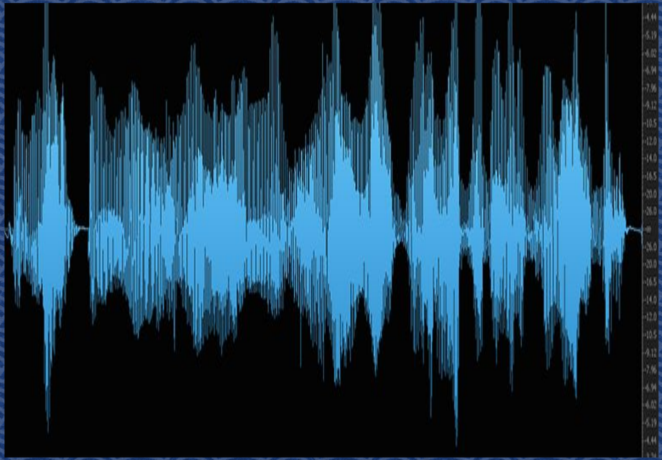
AUTOMATIC TEMPO ESTIMATION METHODS

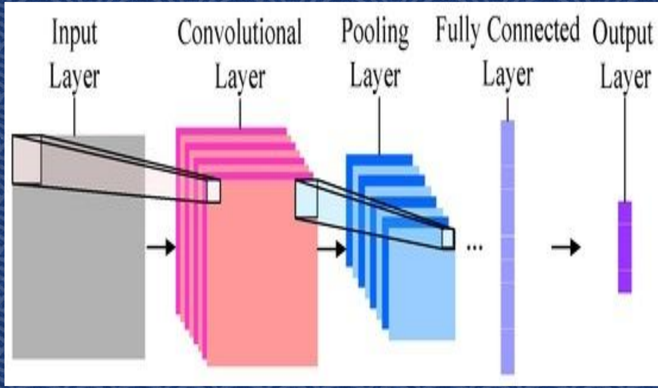
- Sometimes unreliable.
- Generally produce only one answer.

Try to devise one that will be more reliable and can give more than one answer when appropriate

The Data

My MP3 collection:
about 150 audio files, one song each,
hand-labelled with 1, 2, or 3 tempos each





The Methods

- Mel Spectrogram computed by LibROSA
- Convolutional Neural Network

CHALLENGES

- Not enough data
- What loss function to use for multiple tempos?
- Some songs change tempo
- How to represent data to generate features

DEALING WITH TEMPO CHANGES

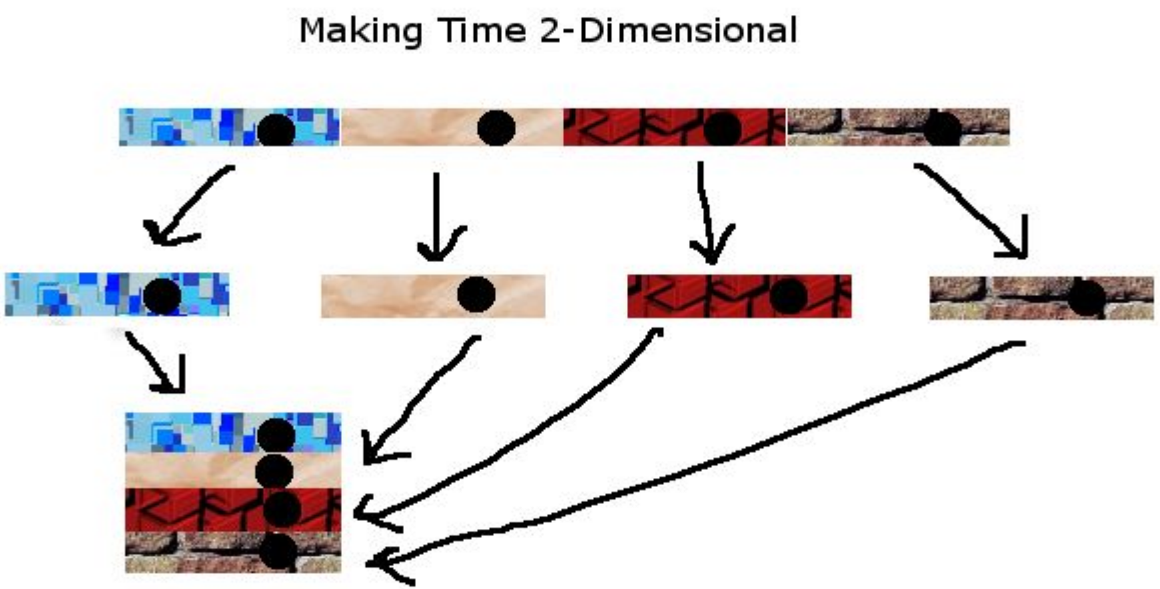
- Cut off beginning and end of each song (since many have tempo changes there).
- Drop songs with tempo changes in the middle.

MAKING TRAINING DATA

- Create training examples by taking multiple random samples from each song. few->many
- Use peaks of LibROSA tempogram() function as “candidate tempos”
- Each sample gets assigned a candidate tempo (randomly chosen from those peaks)
- Simple binary loss: Is candidate tempo close to one of the hand-labeled tempos?

HOW TO REPRESENT THE DATA

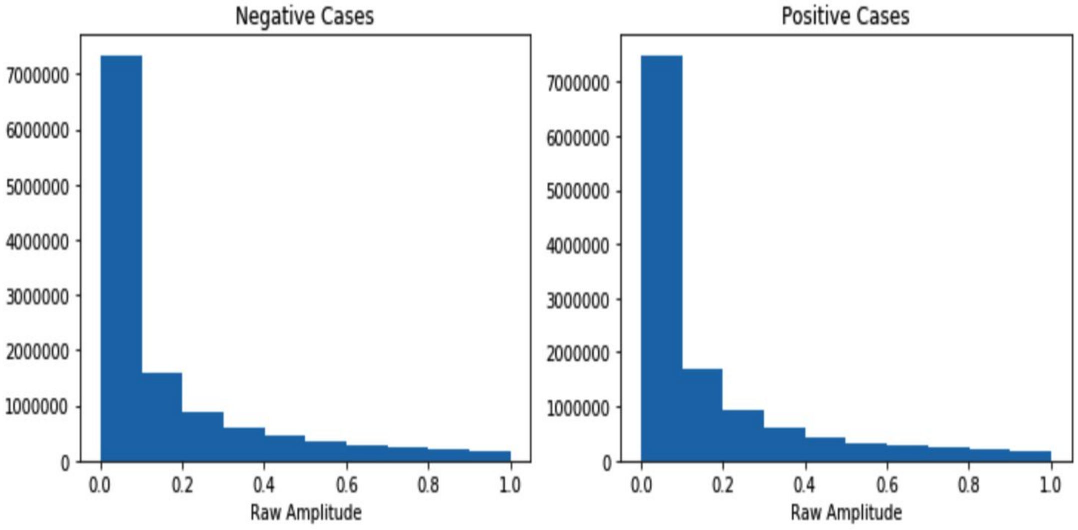
Divide clip into one section for each beat at candidate tempo, and stack the sections



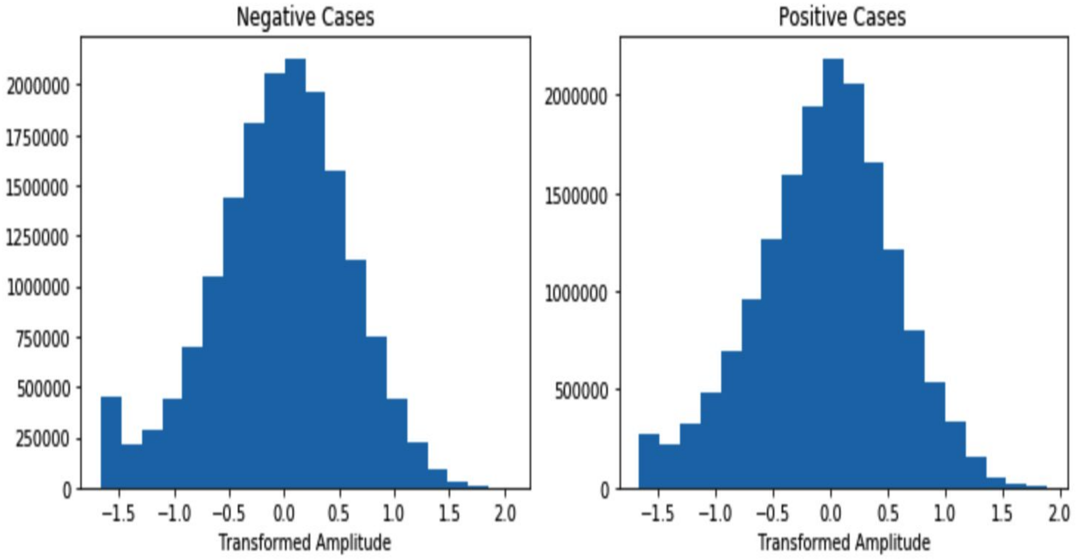
THEN USE THE STACKED DATA AS INPUT TO A 2-DIMENSIONAL CONVOLUTIONAL NEURAL NETWORK

How the data look

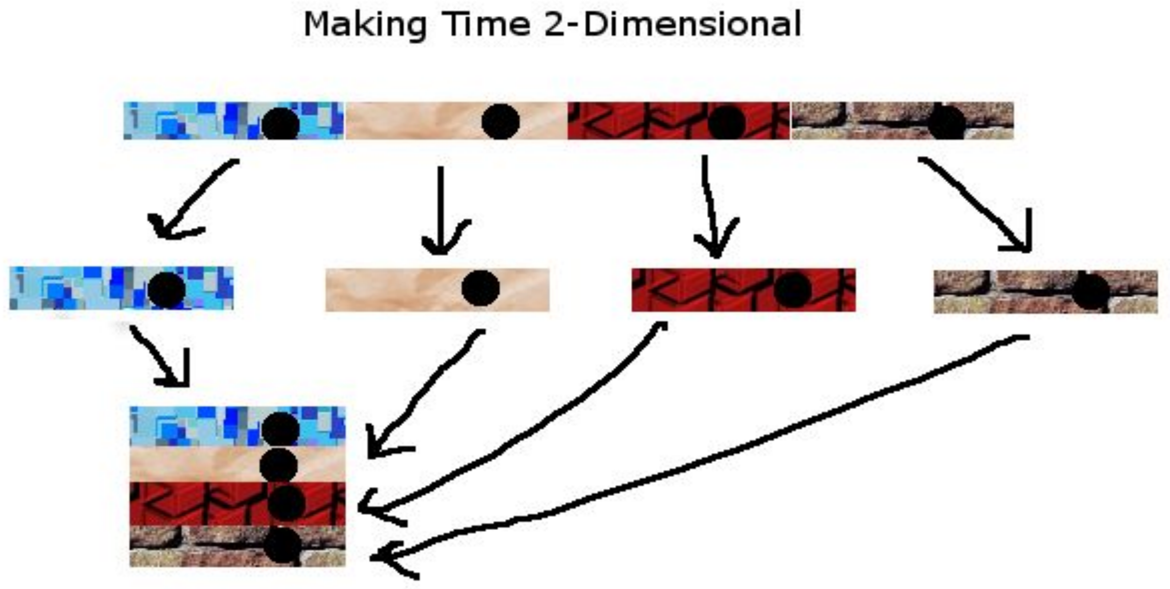
Distribution of Raw Data

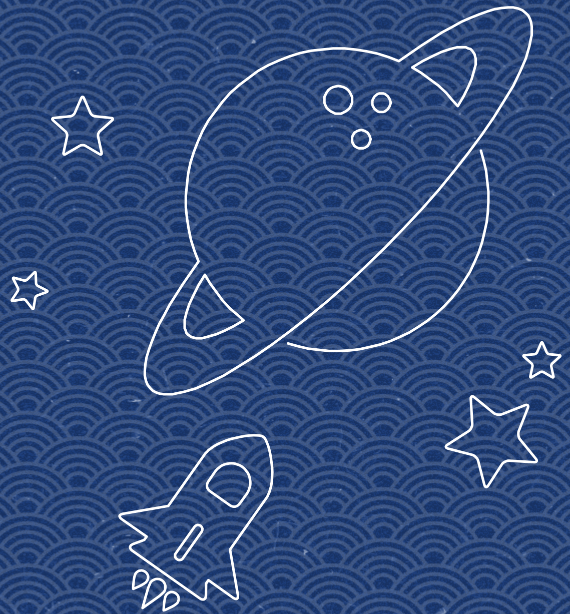


Transformed Data

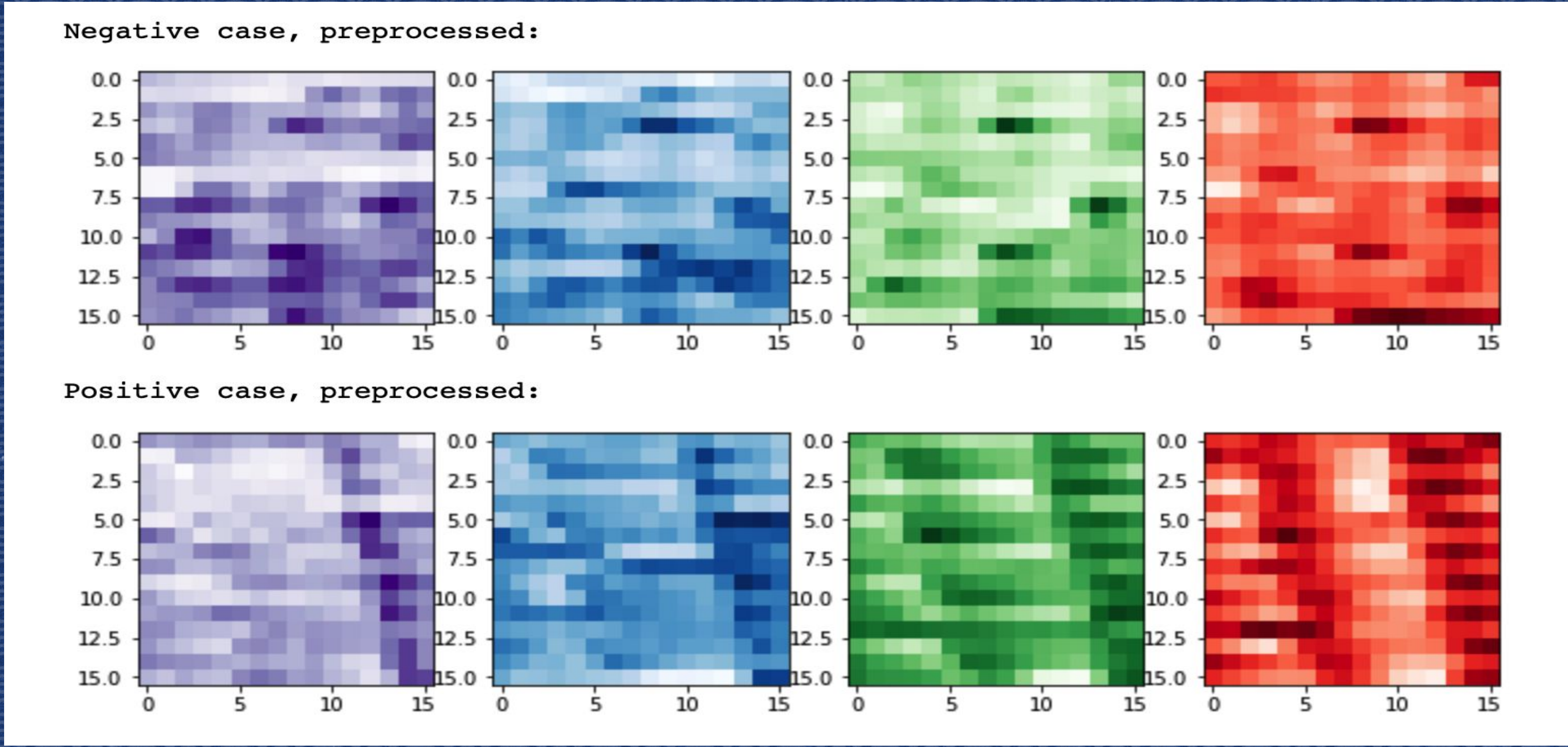


FOR POSITIVE (CORRECT) CASES, EACH BLOCK OF DATA SHOULD HAVE A CONSISTENT VERTICAL PATTERN, AS BEATS GET REPEATED





What do we actually see?



Here the spectrogram is divided into 4 sections, with the lowest pitches in purple and the highest in red. These cases are fairly typical. In the negative case, as expected, there are no clear patterns. In the positive case, there are almost-vertical patterns, but they are downward-sloping.

STATISTICS TO REPRESENT VERTICAL PATTERNS

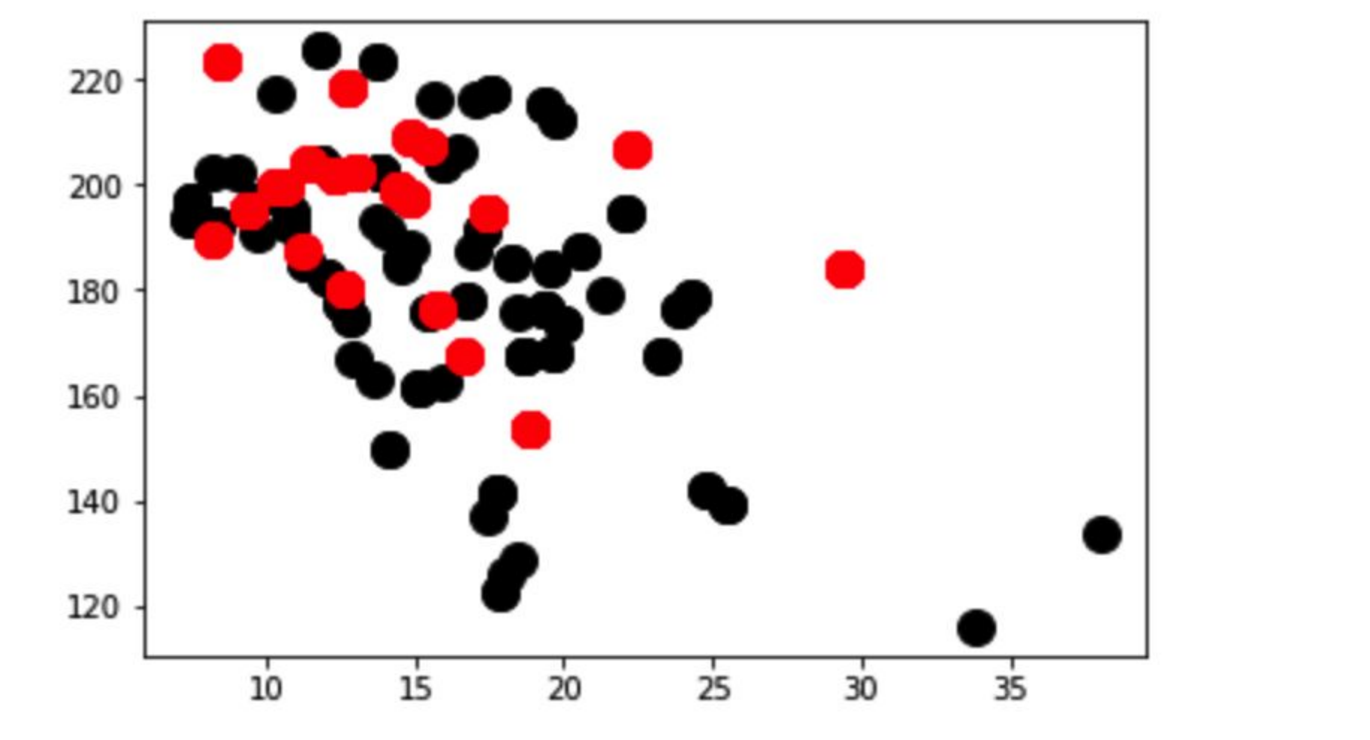
Average variance along vertical dimension

Should be low for positive cases

Average correlation between successive rows

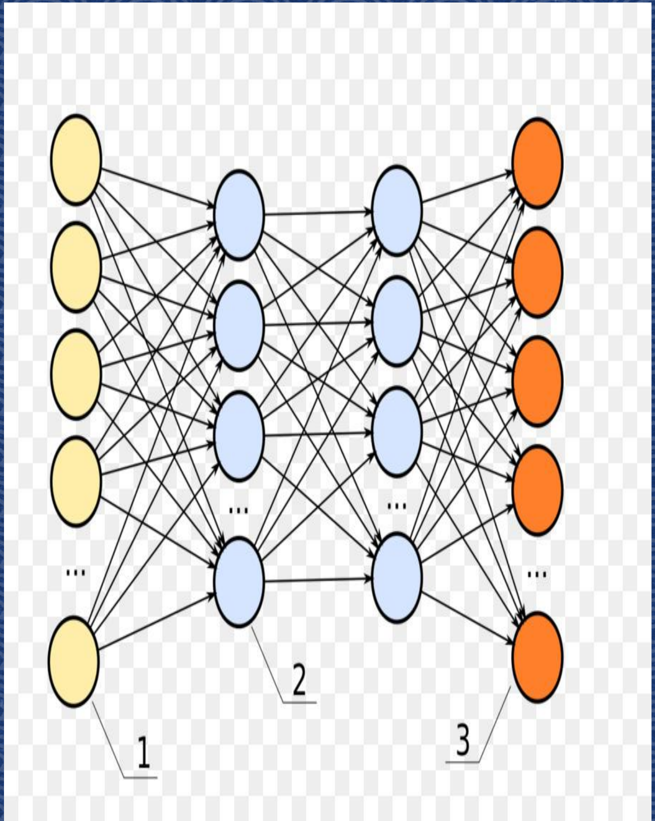
Should be high for positive cases

average correlation



average variance

The positive (red) cases, as expected, tend to have high average correlation and low average variance. The negative (black) cases are more broadly distributed, but they are more common elsewhere.



The Neural Network

STRUCTURE

Output: Sigmoid
Dense(20)
Dropout(.8)
1x4 Convolution, 3 filters
Batch Norm
4x6 Convolution, 25 filters
Dropout(.3)
1x4 Convolution, 12 filters
Batch Norm
1x1 Convolution, 32 filters
Dropout(.1)
1x1 Convolution, 64 filters
Input: 16x16, 128 channels

SALIENT FEATURES

- Narrow convolutions (1x4 and 4x6) instead of square convolutions
- Alternating batch normalization and dropout between successive convolutions
- Very high dropout before top layer

RESULTS

- Validation accuracy 0.91 (after 60 epochs using final version of model)
- This is quite good, considering that many cases are ambiguous

EXAMPLE RESULTS

- **53rdAnd3rdMP 45**
  Predicted: 0.00090704486 Actual: False
- **AHardRainsAGonnaFall 56**
  Predicted: 0.021726133 Actual: False
- **AHardRainsAGonnaFall 62**
  Predicted: 0.017301498 Actual: True
- **InTheHillsOfShiloh 64**
  Predicted: 0.13423629 Actual: False
- **CaliforniaDreamin2MP 112**
  Predicted: 0.93683857 Actual: True

NEXT STEPS

So, so many: for example

- Look at results per song. Subjectively, how does model do at getting correct paces? Are typical failures legitimately ambiguous cases, or is the model really missing something?
- Get data from other human labelers.
- Get more data for underrepresented genres (and time signatures). And a greater variety of artists.

....and so on

See https://github.com/andyharless/paces/blob/master/README.md

THANKS!

github.com/andyharless