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# Music Classification Using Convolutional Neural Networks

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## Abstract

The abstract paragraph should be indented  $\frac{1}{2}$  inch (3 picas) on both the left- and right-hand margins. Use 10 point type, with a vertical spacing (leading) of 11 points. The word **Abstract** must be centered, bold, and in point size 12. Two line spaces precede the abstract. The abstract must be limited to one paragraph.

## 1 Introduction

Music is and has always been one of the most popular forms of art and entertainment. The number of people who use streaming services to consume music has grown to a magnitude of millions in this decade. These services make use of complicated and complex recommender systems to help grow the number of daily active users and to improve their experience of the service. These recommender systems rely on extremely large labeled datasets in order to work properly, and labeling these datasets manually is a very resource-heavy endeavour.

### 1.1 Our Goal

**Music Genres in General** One possible way of labeling songs is doing it by genre though this introduces other difficulties, since these are meant to indicate the artistic nature of music, an aspect which tends to be highly subjective and controversial. Music genres do not have a proper, formal definition and often overlap as well, making music classification by genre a more difficult task to do right.

**Our Primary Goal** Our primary goal was to deliver a solution which can effectively recognize some of the most popular and generic music genres and assign these as labels to songs of music.

## 2 Our Approach

There are many existing solutions and research papers regarding the subject and these show absolutely usable methods and results, though each of them tend to have a major drawback: every solution aims to work in *centralized environments* due to their computational requirements. We decided that our approach had to be able to work on edge devices such as smart phones or other, more constrained environments, even on cost of precision. This decision implied a rather small model size and great model simplicity, this is why we chose to try a simple convolutional neural network.

## 3 The Model

### 3.1 Trial and Error

We went through numerous iterations and tried various convolutional neural network architectures during development. At first we tried to use convolutional windows that would overlap the whole frequency domain and move only in the time domain, since although spectrograms can be regarded

as arbitrary two dimensional data, the two axes have different meanings. This path led nowhere, the model was not able to overfit on a small subset of the dataset. We decided to use simple, rectangular convolutional windows, which could be called standard by now. This approach was indeed able to overfit, meaning it was worth to try learning on the whole dataset. Validation error would cease to decrease after the first few epochs. This would be followed by decreasing the input size of the model by splitting the samples of 30 seconds length into 4 smaller fragments.

### 3.2 The Final Model Architecture

The final model consists of the following layers:

- a convolutional layer with a depth of 32 and a window shape of (2, 6)
- another convolutional layer with a depth of 32 and a window shape of (2, 6)
- a convolutional layer with a depth of 64 and a window shape identical to the previous ones
- a fully connected layer of 512 neurons

Each convolutional layer was followed by a batch normalization layer and a max-pooling layer. L1 and L2 regularizers were adopted to the fully connected layer. The model has an output layer of 10 neurons with *softmax* as activation function.

### 3.3 Hyperparameters

**Activation functions** At first we tried using *ReLU* activations between each layer. This lead to many issues, since in the context of Mel spectrograms negative numbers have significance. Perceiving this, we decided to use *Hyperbolic Tangent* as activation function.

**Loss Function** The loss function used is *Sparse Categorical Crossentropy* since the labels are not one-hot encoded.

**Optimizer** The optimizer algorithm used during training was Stochastic Gradient Descent with a learning rate of 0.01. At first we've tried with *Adam* but it did not perform quite as expected. The next choice was *Adadelta* which showed promising results, but it did not appear to stable due to the fluctuation we have observed on both the graphs of training and validation accuracy.

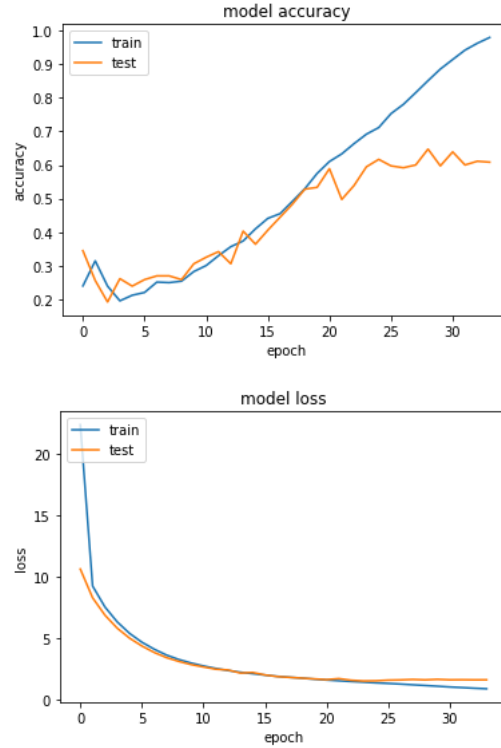
**Number of Epoch and Data Split** The model was trained for 100 epochs with a batch size of 5. 80 percent of the data was used for training, 10 percent was used for validation and the last 10 percent was used for testing.

**Vanishing Gradient** During the training process we've noticed that after a certain number of epochs the validation accuracy would cease to converge. This was due to the Vanishing Gradient problem, which led to the choice of using *Linear* activation between the convolutional layers, leaving *Hyperbolic Tangent* only between the output and the fully connected layer.

## 4 Results

### 4.1 Training and Validation

The model is still overfitting with the validation accuracy being stuck at  $\tilde{60}\%$  and the training accuracy soaring.



## 4.2 Testing Accuracy

The final testing accuracy of the model is **0.61%**. Below are the Classification Matrix and the final Classification Report.

Table 1: Confusion Matrix

| Genre     | Metal | Classical | Reggae | Jazz | Country | Rock | Hiphop | Disco | Pop | Blues |
|-----------|-------|-----------|--------|------|---------|------|--------|-------|-----|-------|
| Metal     | 44    | 0         | 0      | 0    | 0       | 0    | 0      | 0     | 0   | 0     |
| Classical | 0     | 28        | 0      | 0    | 1       | 1    | 0      | 0     | 0   | 0     |
| Reggae    | 1     | 1         | 18     | 0    | 1       | 2    | 5      | 3     | 8   | 5     |
| Jazz      | 1     | 11        | 0      | 28   | 1       | 1    | 0      | 0     | 1   | 2     |
| Country   | 0     | 2         | 0      | 3    | 20      | 1    | 0      | 0     | 0   | 4     |
| Rock      | 12    | 0         | 0      | 2    | 5       | 16   | 4      | 2     | 1   | 4     |
| Hiphop    | 7     | 0         | 1      | 0    | 0       | 0    | 28     | 0     | 1   | 2     |
| Disco     | 4     | 1         | 4      | 0    | 1       | 9    | 7      | 8     | 7   | 2     |
| Pop       | 0     | 3         | 1      | 0    | 3       | 2    | 2      | 0     | 35  | 2     |
| Blues     | 1     | 1         | 0      | 5    | 2       | 0    | 0      | 1     | 0   | 20    |

## References

References follow the acknowledgments. Use unnumbered first-level heading for the references. Any choice of citation style is acceptable as long as you are consistent. It is permissible to reduce the font size to small (9 point) when listing the references. **Remember that you can use more than eight pages as long as the additional pages contain only cited references.**

[1] Alexander, J.A. & Mozer, M.C. (1995) Template-based algorithms for connectionist rule extraction. In G. Tesauro, D.S. Touretzky and T.K. Leen (eds.), *Advances in Neural Information Processing Systems 7*, pp. 609–616. Cambridge, MA: MIT Press.

[2] Bower, J.M. & Beeman, D. (1995) *The Book of GENESIS: Exploring Realistic Neural Models with the GENeral NEural Simulation System*. New York: TELOS/Springer-Verlag.

Table 2: Classification Report

| Genre     | Precision | Recall | F1-Score | Support (number of samples) |
|-----------|-----------|--------|----------|-----------------------------|
| metal     | 1.00      | 0.63   | 0.77     | 70                          |
| classical | 0.93      | 0.60   | 0.73     | 47                          |
| reggae    | 0.41      | 0.75   | 0.53     | 24                          |
| jazz      | 0.63      | 0.74   | 0.68     | 39                          |
| country   | 0.67      | 0.59   | 0.62     | 34                          |
| rock      | 0.35      | 0.50   | 0.41     | 32                          |
| hiphop    | 0.72      | 0.61   | 0.66     | 46                          |
| disco     | 0.19      | 0.57   | 0.28     | 14                          |
| pop       | 0.73      | 0.66   | 0.69     | 53                          |
| blues     | 0.67      | 0.49   | 0.56     | 41                          |

Table 3: Classification Report Averages

| Type             | Precision | Recall | F1-Score | Support (number of samples) |
|------------------|-----------|--------|----------|-----------------------------|
| Macro Average    | 0.63      | 0.61   | 0.59     | 400                         |
| Weighted Average | 0.71      | 0.61   | 0.64     | 400                         |

[3] Hasselmo, M.E., Schnell, E. & Barkai, E. (1995) Dynamics of learning and recall at excitatory recurrent synapses and cholinergic modulation in rat hippocampal region CA3. *Journal of Neuroscience* **15**(7):5249-5262.