Convoluted Cosmos: Automatic Classification of Galaxy Images using Deep Learning

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Abstract

In this project, Galaxy Image Classification using a Deep Convolutional Neural Network is presented. The galaxy can be classified based on its features into three main categories, namely: Elliptical, Spiral, and Irregular. The proposed deep galaxy architecture consists of one input convolutional layer having 16 filters, followed by 3 hidden layers, 1 penultimate dense layer and an Output Softmax layer. It is trained over 3232 images for 200 epochs and achieved a testing accuracy 97.38% which outperformed conventional classifiers like Support Vector Machine and previous research contributions in the same domain of Galaxy Image Classification.

Introduction

The classification of galaxies based on shape, size and color is important because understanding galaxy morphology help us better understand our universe by assisting us to answer questions regarding the distribution of galaxies within the universe.

Thanks to technological advancements in astronomy and telescope design , the rate at which these pictures are captured has increased, and as a result the size of the database is growing very rapidly.

Thus, our goal for this project was to design an architecture that performs classification automatically and reproduces the results equivalent to that done by manual classification.

Proposed Method

Terminologies used:

1. Convolution Neural Network(CNN)
2. Softmax
3. Dropout
4. Deep Learning
5. Galaxy
6. Galaxy Image Classes- Elliptical, Spiral, Irregular

Dataset was obtained from Kaggle and NASA Hubble-Space Gallery Website.

Galaxy Types	Total Images	Training Set	Validation Set	Testing Set
Elliptical	1464	1000	400	64
Spiral	1464	1000	400	64
Irregular	1686	1232	390	64

Table: Different classes with number of images for training, validation and testing.

Construction of Convolutional Neural Network model : Python using the Keras framework.

CNN architecture comprises :

- 1 Input Convolution 2D layer
- 4 hidden layers
- 1 penultimate dense layer
- 1 output layer

- Filter Size : 3 x 3
- Image Size :128x128 pixels
- Batch size :64
- Epochs :40
- Timestamps :10 per epochs

$$x^{\ell}_{ij} = \sum_{a=0}^{m-1} \sum_{b=0}^{m-1} \omega_{ab} y^{l-1}_{(i+a)(j+b)}$$

FIg. 1: Equation for Convolution Neural Network

Model Architecture

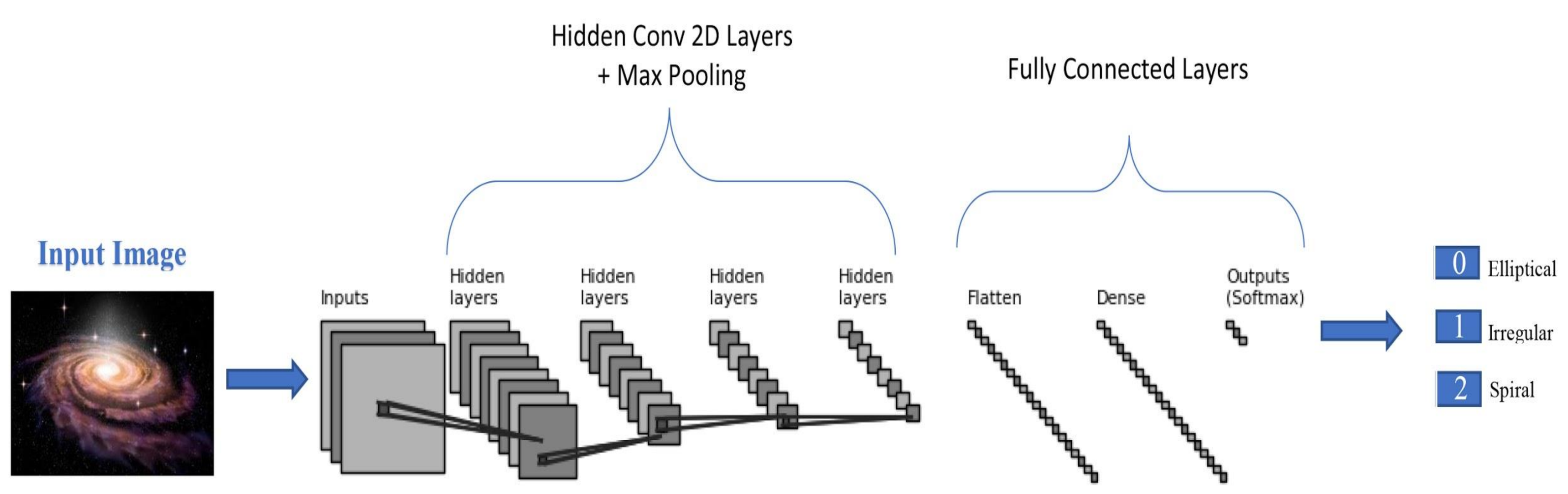

Fig.2- The Architecture of Convolutional Neural Network for Galaxy Classifications

Experimental Results and Discussion

Technologies Used :

1. Windows 10 machine: Intel dual-core i5 processor clocked at 2.40 Ghz with 8GB RAM and a dedicated Nvidia Geforce 940M GPU.
2. Nvidia DGX 1(8X Tesla V100) Supercomputers servers: 5120 Nvidia Tensor Cores and a computing power of 960 TeraFlops (for Model).
3. Spyder 3.0.0, Jupyter 1.0.0 and Python 3.5.2 using Keras 2.1.3 framework (for Python Code).

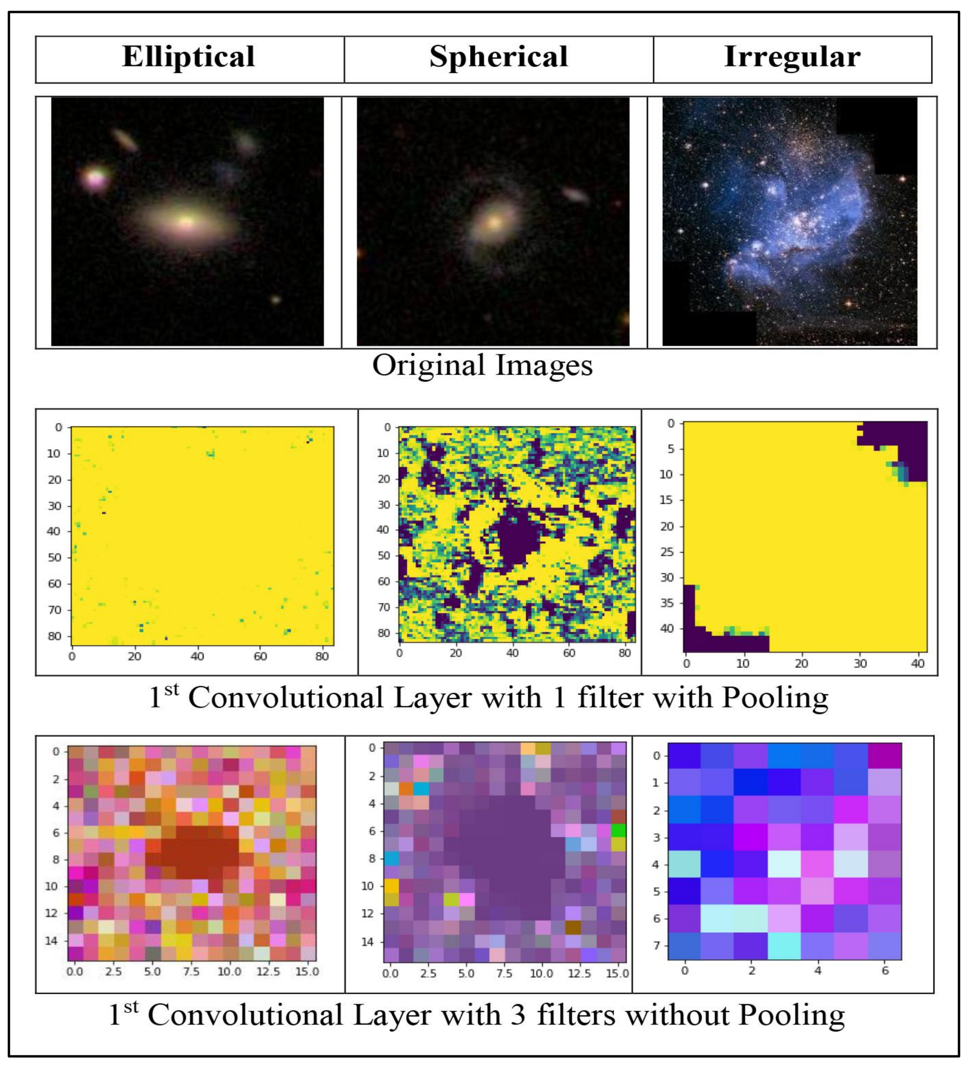

Fig.3: Visualizing Image Transformation in 1st layer with and without Pooling.

Epoch :- 200
Training Accuracy :- 99.53%
Validation accuracy :- 98.48%
Test accuracy :- 97.398%.

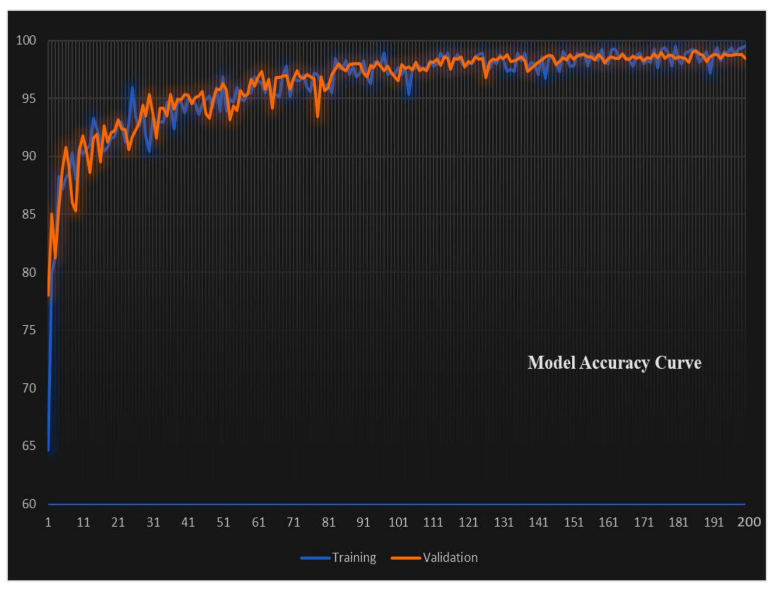

Fig.4: Macy Curve

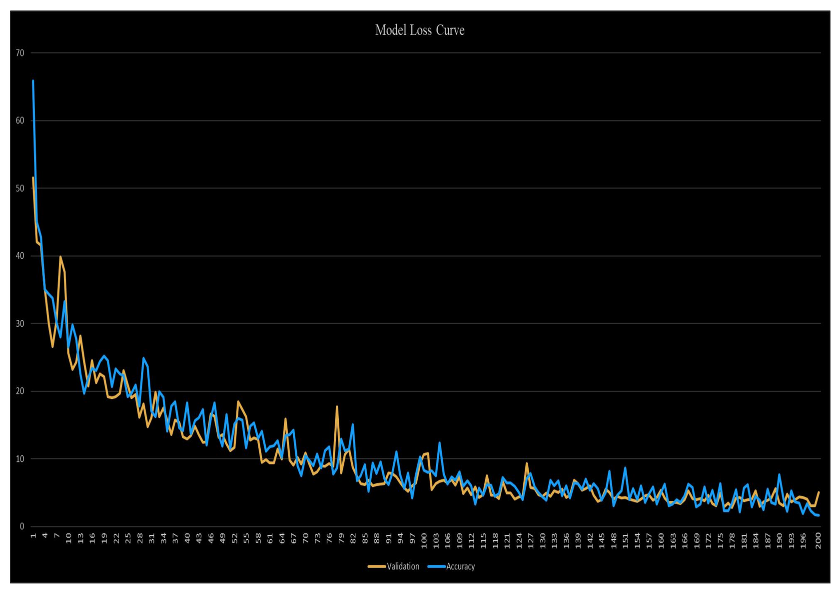

Fig.5: Model Loss Curve

Testing results were obtained in binary form as:
0 - Elliptical
1 - Irregular
2 - Spiral

If we calculate accuracy using formula

Acc= Correct Prediction/Total Images

then ,we find 3 types of image accuracy:
Elliptical : 100%
Spiral : 100%
Irregular : 92.1875%

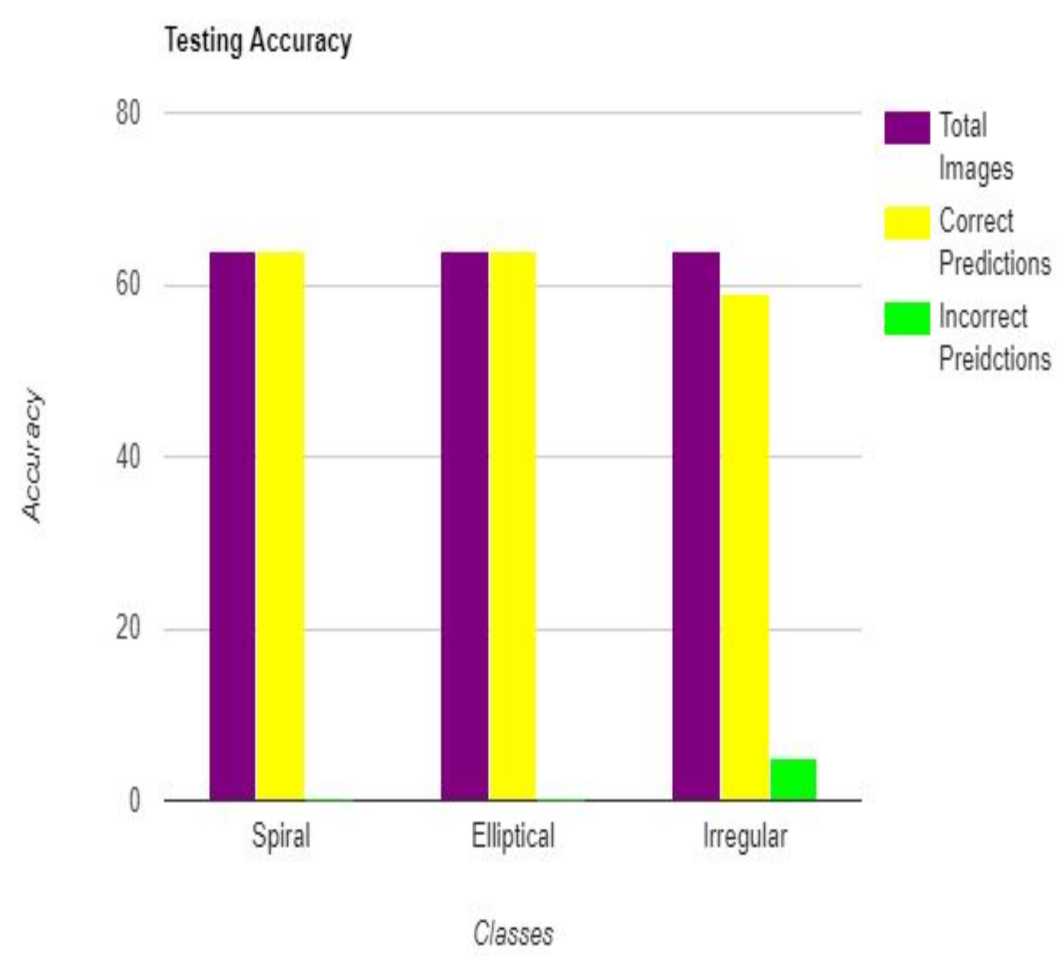

Fig.6: Testing Accuracy Graph

Conclusions

The Project will be helpful for astronomical scientists and cosmologists.It will help to classify huge collection of Galaxy images without manual effort of viewing each image individually. The Project can be fine-tuned for further classification of galaxies into their subclasses. The testing time was reduced to few seconds by saving the CNN weights file as h5 file and thus it will be working on real time scenarios also.

References

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4. Star-galaxy Classification Using Deep Convolutional Neural Networks

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