DeepBench: Open-Source Tools for A.I. in the Sky

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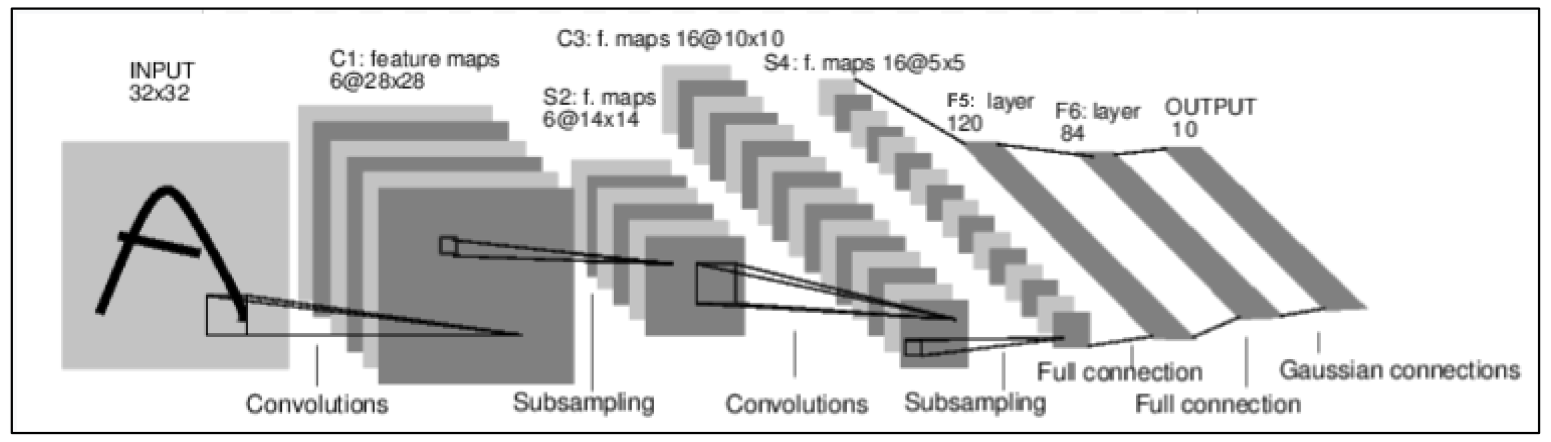
Introduction

In recent years, the intervention of Deep Learning as a promising tool for science has simultaneously driven the demand for resources that aid in understanding and developing new learning models. Deep Learning has shown promise in being able to solve classification and regression problems in Astronomy and Physics



Pictured above is a Convolutional Neural Network (CNN) used for classification of images. More specifically, this is a LeNet-5 architecture proposed by Yann LeCun. CNNs are a popular architecture in machine learning as they excel in image classification[1].

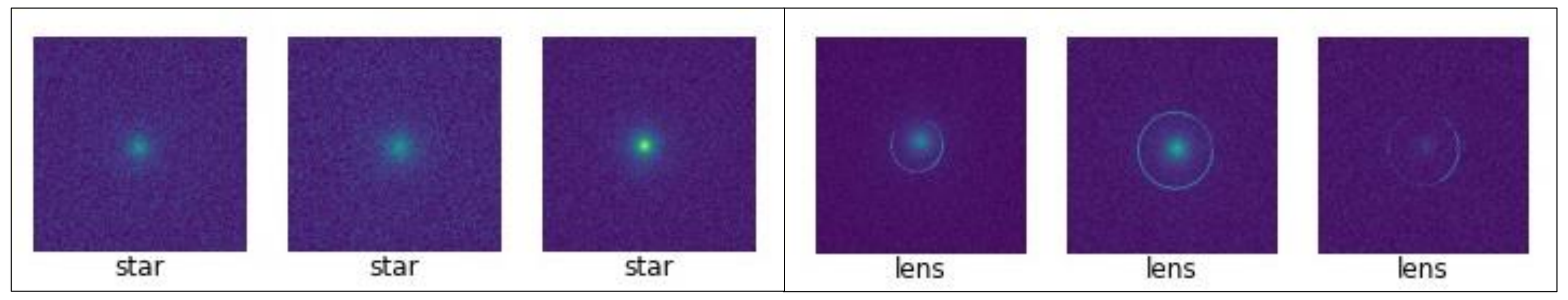
Although Deep Learning has yielded promising results, it is often difficult to understand the patterns that a neural network is recognizing and whether unintentional bias is being introduced. Without careful and tedious analysis, these errors can invalidate findings. The purpose of *DeepBench* is to provide simple, insightful benchmarking tools to probe these issues on simple inputs before applying to data.

It is currently in development and will provide a suite of toy-data making tools allowing researchers and students to generate geometrically simple data. Eventually, it will be usable with another project, *DeepUtilities,* which aims to streamline the process of designing neural network architectures even more.

The Deep Skies Lab was founded in 2017 to connect researchers in Astronomy and Artificial Intelligence and explore the intersection of those fields. It is an international collaboration whose members come from Brazil, Canada, and the United States. Visit *deepskieslab.com* to learn more.

Current Features

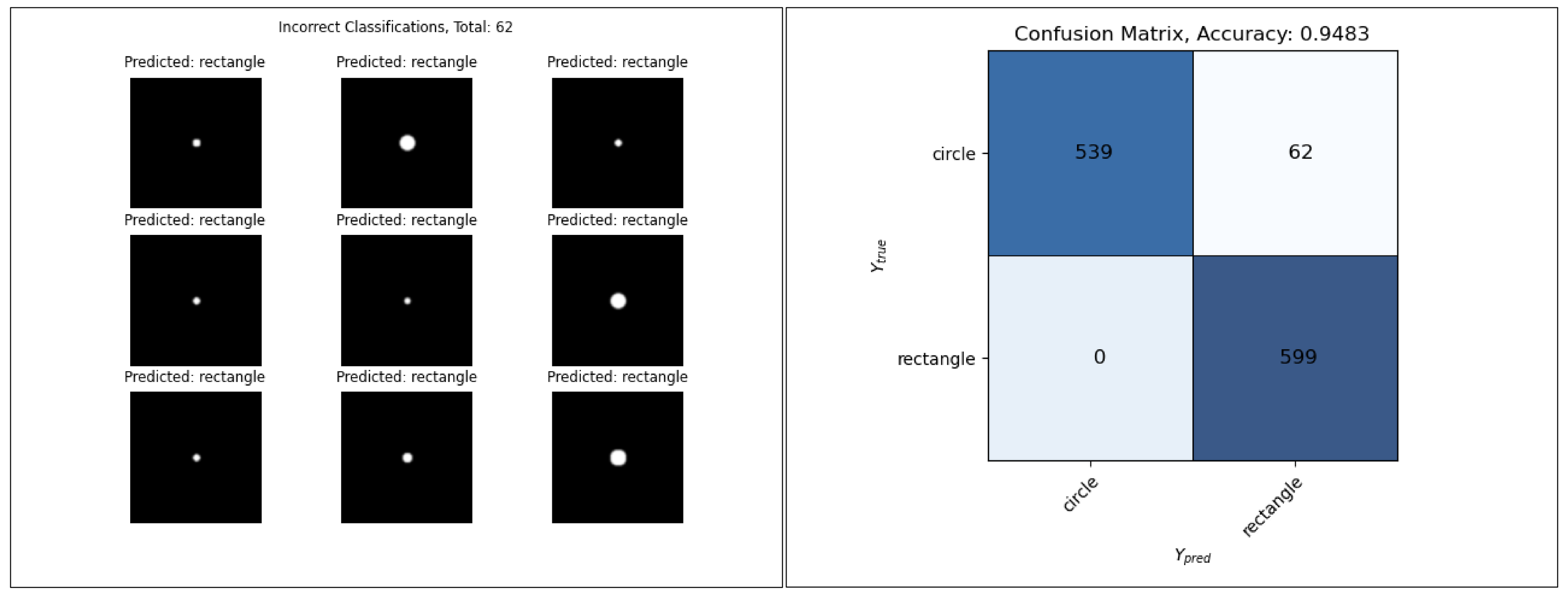
A necessary feature of *DeepBench* is to collate various geometric features to approximate physical features of astronomical objects. The program can create geometrical representations of galaxies, stars, and strong lensing events. The individual shapes composing astronomical objects are also available to the user to make their own composite objects. It can also add Poisson-generated noise and Gaussian blurring to images. The image meta data is stored in a DataFrame which can then be saved as a comma-separated file.



Pictured above are star and gravitational lenses created in *DeepBench*. They both utilize a Moffat distribution[3] to represent stars, but a gravitational lens can also be drawn without a star.

Performance on Classifying Images

As testing for the various elements of *DeepBench* and my own understanding, I learned to make Convolutional Neural Networks (CNNs) and train them on images from *DeepBench*. The training set included a series 6000 randomly-sized circles and rectangles which are basic shapes in *DeepBench.* The images were also convolved with a Gaussian blur. In this case, the CNN used performed poorly on recognizing circles as such when their sizes decreased as can be seen in the leftmost plot.



Classification of circles and rectangles. On the left is a subsample of the incorrect classifications from the validation set. On the right is the non-normalized confusion matrix showing that the incorrect classifications are coming from true circles being labeled rectangles.

Future Additions

As the project currently stands, it is in pre-alpha development. Many new features included below will be added before the release of *DeepBench:*

- Unit tests for developers
- More Jupyter notebook examples
- Support for *hdf5* file formats and *yaml* configuration files
- Generate new types of data
  - Stellar Light Curves
  - Spherically-projected datasets for *DeepSphere*[4]
- Include benchmark datasets

Acknowledgements

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References

[1] *Figure 2*. Architecture of LeNet-5, a Convolutional Neural Network, here for digits recognition. Each plane is a feature map, i.e. a set of units whose weights are constrained to be identical. Adapted from "Gradient-Based Learning Applied to Document Recognition" by Y. LeCun et al., November 1998, Proceedings of the IEEE

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[4] Perraudin, N., Defferrard, M., Kacprzak, T., & Sgier, R. (2019). DeepSphere: Efficient spherical convolutional neural network with HEALPix sampling for cosmological applications*Astronomy and Computing, 27*, 130–146.