The Role of Machine Learning in Astronomy

Pankhudi Saraswat[1] and Divya Jain[2*]

[1]UG Scholar, Computer Science and Engineering, The NorthCap University
Gurugram, India, E-mail: *pankhudisaraswat07@gmail.com*

[2]Assistant Professor, Computer Science and Engineering, The NorthCap University
Gurugram, India. *Corresponding Author E-mail: *divyajain1890@gmail.com*

Abstract: Machine learning is one of the most immensely growing field these days. It is gaining attention quickly and has people all around the world in awe of the tasks it can achieve. Machine and deep learning are a huge milestone while also being a great step in direction of technology as they can help us in achieving results with high precision. Astronomy is one such field that is reaching new levels with help of AI and machine learning. Through this paper, authors try to bridge the difference between the two fields and try to show how various machine learning algorithms have been implemented in the field of space research and have made work much easier and efficient. This article also addresses how deeply connected these two fields are how they can completely change the future of inventions and space information.

Keywords: Machine learning, Astronomy, Artificial Intelligence, Technology

I. INTRODUCTION

Astronomy is a field that has attracted and fascinated people for decades. The sky with its infinite limits and numerous secrets has always attracted people to unravel the countless mysteries. Here authors discuss about various projects where Machine Learning (ML) and astronomy come together and how these projects have been a huge success to both the industries. As these two fields intermingle with each other new horizons open for researchers.

The objective of this paper is to make sure that readers are well versed about various projects and future scope of collaboration of these two industries. As technological advances will always happen in both ML and Space exploration, we bring forward new ventures to the readers. Be it being able to predict chronic illnesses [28] or help in landing the most advanced technological asset on a planet ML has its roots almost everywhere now. The input data has been increasing and increases exponentially every day and that's why astronomy and technology work together now. One such modern technology tool that astronomers use these days is ML and Deep Learning [1]. ML is the study of algorithms and then using them for solving everyday problems. ML is an integral part of space explorations and is a vital measure in this age of data and automation. As astronomy crosses new boundaries ML proves to be extremely useful for the same as the various algorithms of machine learning speed up the process and helps researchers in getting much accurate data in efficient ways. Because of these benefits offered by ML and DL, there is extensive usage of them in space searches and researchers are also using it greatly these days. As space missions operate in extreme conditions, conditions that aren't fathomable for both humans and machinery. Thus, research is carried out remotely and therefore space explorations always have room for advances in technology. As technology advances various robotic vehicles used in astronomy like rovers, orbiters, and other data collector and analysis tools accompany the astronauts on their expeditions. With proper use of ML research get to more precise results and in much lesser time.

The figure 1 represents the use of machine and deep learning in space research. The use of ML is not limited to any one field in space exploration; thus, it is used in various missions and tools for research. The given below are the most common and widely used applications (more explanation).

- Morphological classification of galaxies, classification of asteroids, Star/Galaxy classification.
- Photometric redshift of galaxies (Regression).
- Anomaly detection in Space related instruments (Space Shuttle Main Propulsion System).
- Anomaly detection in astronomical observations.

ML is a gigantic field and has limitless new options. It is subdivided into two main categories for easy completion of tasks: supervised and unsupervised. Authors can find usage of both the types in space and astronomy research as scientists use them according to the requirement of the outputs and working method of project.

In supervised learning [24-27], authors have an idea of what our result will look like, and therefore our goal is to train the data set in the best possible way to get the desired output. After this training is complete, authors provide the machine with new data and then this new data set is processed with the supervised learning algorithm and in the end, authors are provided with new labelled data. Thus, in supervised learning, our prime focus is to make sure that authors train our machine with a variety of data set for correct outcomes. Furthermore, Supervised Learning is subdivided into two more categories namely, classification and regression.

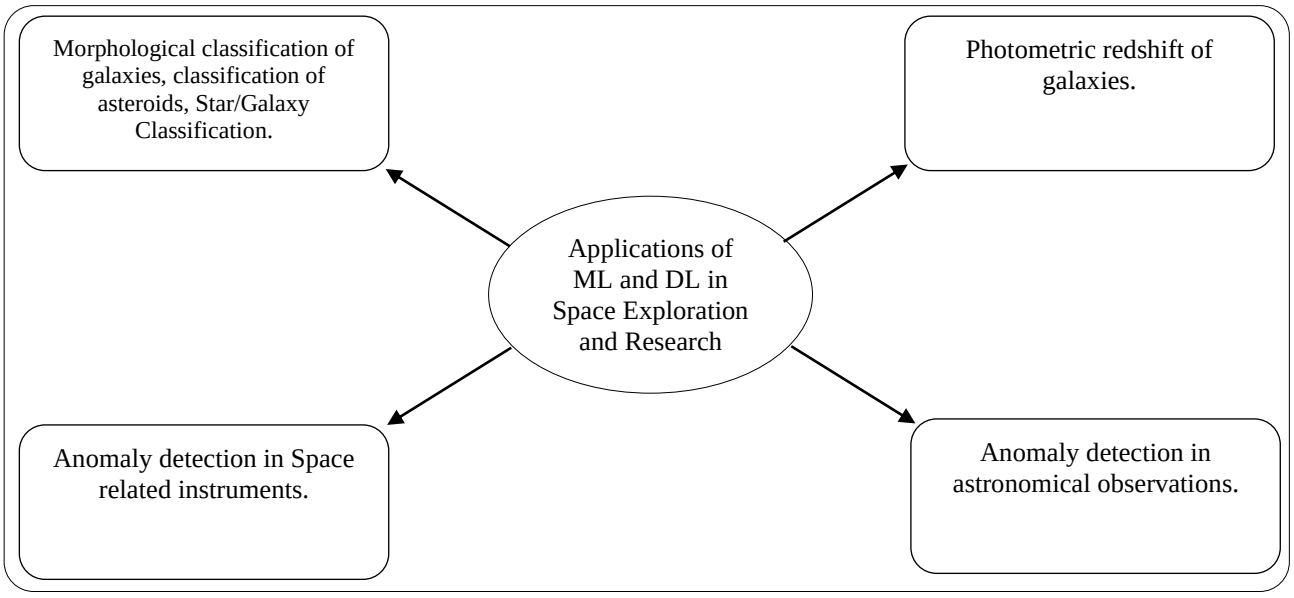

Fig.1. Applications of ML and DL in space exploration and research.

Unsupervised learning works by finding patterns in the data set provided and the data given to the machine is neither labelled nor classified. As unsupervised learning can automatically identify patterns and structures in data present therefore it is a vital tool in exploratory analysis. Once the model/machine is properly trained then it can easily find patterns in the data provided and can easily predict patterns. Table 1 represents the brief about the two types of learning whereas table 2 represents examples of algorithms.

Table 1. Brief about Supervised and Unsupervised learning.

	Supervised Learning	Unsupervised Learning
Discrete	Classification/Clustering	Categorization
Continuous	Regression	Dimension reduction

Table 2. Some algorithms of supervised and unsupervised machine learning.

Supervised Learning [29]	Unsupervised Learning [30]
Linear regression for regression problems.	K-means for clustering problems.
Random forest for classification and regression problems.	Apriori algorithm for association rule learning problems.
Support vector machines for classification problems	Anomaly Detection
Decision Trees	Singular value decomposition
Neural Networks	Principle Component Analysis

The organization of this paper is as follows: Section 2 talks about challenges of Machine Learning and its usage in some NASA projects. Section 3 is literature review of research papers written which are related to the topic of Artificial Intelligence, Machine learning and space research. Section 4 is the conclusion of the paper.

II. CHALLENGES WITH MACHINE LEARNING

Machine learning is a boon to the world, but every like coin has two sides, and it also has some challenges that are yet to overcome for a danger-free application. First and foremost, the memory space taken by neural networks is huge as augmented neural networks store huge amounts of data and hence, they require large working memory and storing space. Authors also lack the ability to perfect image classification and object detection [2-3] as most of the ML systems still lack this technique. In some countries where funds for research projects are not readily available scientist often face this problem and hence many times great projects fail to exist because of financial issues.

One of the biggest fears that data scientists have from using Artificial Intelligence [4-6] is that what if the system becomes too intelligent? The likelihood of such a scenario especially in astronomy related works being real is extremely small as authors have not advanced to that extent in technology. Our Artificial Intelligence or Machine Learning systems aren't equipped enough to develop their own intelligence or system to an extent of overthrowing mankind. Authors still need to know how deep nets training work [7] Scientists find new information about the same every day and research for years over every new piece of information, moreover, with a database as wide as space research scientists often get hesitant with using machine learning but slowly and surely things are changing. As authors are gathering more data about the exotic astronomical event the usage of AI in space research is also increasing.

Even though using ML comes with complications still the positives of this asset greatly outweigh the negatives. Astronomers and scientists have been using machine learning for a long time now and the results have been nothing less than satisfactory. Big space organizations like NASA, ISRO, KARI have incorporated Machine Learning in various projects and have had successful past as well as ongoing projects. Some of NASA projects are listed below in table 3.

I. LITERATURE REVIEW

As machine and deep learning technologies mature with every new research, they find more practical applications in various fields, one of them being space exploration. A lot of big names like Elon Musk and Jeff Benzos have invested a lot in AI research for space exploration. They believe that this will open new frontiers for astronomy and human history as well. Elon Musk has been heavily invested in

various projects like SpaceX and OpenAI while Jeff Benzos has revealed that his company has come up with a new lunar lander. Experts are now traversing how machine learning and AI can be used to classify exoplanets and solar systems on their own. Machine learning enables a "smart" method to tackle every problem.

In [14] authors discuss the topic of using machine learning to improve the reliability, cost-effectiveness, and science return of space missions. Space missions are extremely costly and thus have a high cost of failure. Therefore, any aid provided by machine learning or AI must be reliable and a strong investment only. The author also states a well-acknowledged fact that using machine learning in any field can be a bit risky. Even though the possibility of algorithms to jeopardize the task is highly unlikely still for scientists and researchers to use machine learning these algorithms must be safe. Changes and the challenges that future algorithms must overcome to be more efficient are also proposed.

Table 3. NASA Projects involving Machine learning and AI.

NASA Projects	Source	Algorithm Used	Applications
Spirit and Opportunity rovers	[8]	AutoNav	Helpful in tasks like navigation and driving system for self-driving Mars rovers for exploration
Mars's rovers	[9]	AEGIS (Autonomous Exploration for Gathering Increased Science)	Does basic studies on a picture and then sends to NASA scientists for further research.
Planetory Spectrum Generator	[10-11]	Linear Regression and Convolutional Neural Networks.	Exploring exoplanets and measuring atmospheric spectrum
Robonaut	[12]	Machine Learning	Works out a way on how to complete the tasks assigned by the astronauts
G.P.S for moon (In progress)	[13]	Neural Networks	If someone is lost on the Moon, this system works towards finding their location based on the images already fed to the database of the virtual moon.

In [15] writers reflect on the difference between space and terrestrial embedded hardware. This research also focuses on how ML and DL in space can be used in Mobile and Embedded Computing (MEC). The author puts forward how HSD data helps in detecting wetlands, rescuing people from natural disasters, and monitoring oil spills, etc. Deep Learning also helps in saving power consumption during the process of sending satellite imagery as neural networks compress the image data and transmission is thus less power consuming. This research work also brings forward a list of various advantages Deep Learning models can provide to space research and challenges as well as new opportunities for machine learning to broaden the horizon of space research.

In [16] authors explain the increase in data in astronomy and astrophysics. As students from these respective fields do not know how to operate and work with such big data the authors put forward astroML which is an initiative module for machine learning and data mining on python. The paper decodes the working of astroML and its purpose. astroML is a python package that works on data using NumPy, scipy, and ski-kit learn. the paper also talks about examples where astroML package has been used on provided data. one of the best features and a high advantage of astroML is that it is open-source and is freely available. it places its priority in providing a light code-based platform for researchers.

In [17] the author describes how astronomy as a field is rapidly growing, and hence the data is increasing. This massive surge in data has escalated data-driven astronomy. In light, of this, the author

explains the emergence of machine learning. The work also explains the techniques of Machine Learning and Deep Learning like supervised learning, evaluation methods, Support Vector Machines, Random Forests, and shallow Artificial Neural Networks with a lean towards the topic of unsupervised learning. Authors see how Unsupervised learning algorithms play an important part in scientific research as they can be used to extract new knowledge from existing datasets, thus, helping in discoveries.

Image analysis is one of the most salient features of machine learning. In [18] authors refer to the use of image analysis for high accuracy data. The paper talks about large astronomical surveys like SDSS [19], LSST and as these surveys produce hundreds of gigabytes of data in which millions of stars and galaxies are detected so it is not manually possible to process all this data, so researchers take help from Machine Learning and its numerous algorithms for better results. Once all data is collected, a channel of various algorithms is needed to extract serviceable information.

In [20] authors throw light on SKYNET through the first press release of this new neural network training algorithm. SKYNET has the ability of training huge and deep forward neural networks for use in supervised and unsupervised learning applications. It is extremely flexible and has a wide array of applications as SKYNET can do the most trivial tasks but at the same time, it can also solve astronomical problems focusing on the recovery of blurred and noisy images, the identification of gamma-ray busters, and many more. SKYNET has chances of colossal future development as it will expand upon many of the current features and the authors state that they are working on adding new features like activation functions, pooling of nodes.

Many machine learning techniques are performed using artificial neural networks (NN) and hence they are predominant in the field of astronomy as well. In [21] authors propose SKYNET Graff which is an efficient and strong training algorithm for neural network. It is capable of training enormous feed-forward networks. The paper also talks through the final observations from applying SKYNET within BAMBI algorithm to stimulate Bayesian speculation in cosmology as BAMBI is used to solve problems related to cosmological parameter estimations and model selection. The authors also break the ice on the application of SKYNET to gamma-ray busters.

The authors in [22] offer a new method to regenerate astronomical light curves and to make the analogy between image patches and relevant pieces in time series. The authors back up their work by proofs and claim that the new method can help in overhauling the light curves with the obtained information.

In [23] authors outline on the construction of a deep convolutional neural network which has the potential to reproduce the sensitivity of a matched-filtering search for binary black hole gravitational-wave signals. The authors also conclude that the network resulted from their analysis can classify signal from the noise with a performance that imitates that of match filtering applied to the same data sets.

II. CONCLUSION

Through this paper, authors aimed to establish that the collaboration of Machine learning and astronomy has huge potential and can take the world of research to new heights. The role of machine learning in space exploration is mainly divided into data transmission, visual data analytics, navigation, and rocket landing. Both the fields have information that only keeps on expanding every day thus opening new horizons. This paper briefly summarized how some ML algorithms are currently in use or have been part of big space exploration projects and they continuously provide improved and precise results only. Soon all these projects might be heavily influenced by ML and soon spacecrafts may operate with Artificial Intelligence only as new innovations are taking place every day.

ML and space research put together can bring a lot of information for us. Authors can tackle the problems which have been kept behind for a long time and explore new things about our history in this universe. Astronomy and space research have been around for a long time whereas ML is a new field for many so authors hope the readers will be inspired to venture into this new field and find more interesting things.

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Ethical statement: The authors declare that they have followed ethical responsibilities.

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