**ADVANCED MACHINE LEARNING PROJECT ANALYSIS REPORT**

**Introduction**

Deep learning is an advanced technique in machine learning. The advanced machine learning models were built on a neural network model that helps provide solutions for complex issues. This is an algorithm that makes the computer learn from data and we check the algorithm performance on tasks. The neural network model was built on layers, neurons/nodes. The layers and nodes were interconnected and helped in the learning of algorithms on complex issues of data. The layers make the data pass over the layers to learn from the data. The nodes are well organized to capture the complex patterns and relationships between the variables.

Deep learning models were especially fit for solving complex and large data sets. The data as image recognition, speech detection, and natural language processing. The algorithm is able to learn from the data and take the features which are necessary for analysis. These models will select the variables that are significant for identifying the patterns without manual selection of variables. In recent years deep learning usage has grown rapidly. It is applied in a variety of applications as well as many industries. We are focusing on image processing which is the most popular application of deep learning used for the latest applications such as image classification, object detection, and image segmentation.

**Convolution neural networks**

* Convolutional Neural Networks (CNNs): The algorithm was developed to identify the patterns of images sent by rovers. The networks can detect the objects by patterns in the image
* Recurrent Neural Networks (RNNs): It advanced method that can be able to train on data sequentially which is telemetry, weather, and atmospheric data, and analyze the relationship between points and feature values.
* Long Short-Term Memory (LSTM) Networks: These are networks of RNN that can handle dependencies and can retain information over a period. These networks are developed to process the time series data from weather, atmosphere, and telemetry devices
* Generative Adversarial Networks: These networks are used to generate synthetic data such as images and videos of Mars’s surface. The algorithm learns data from underlying data distribution and it will generate samples that are similar to real-world data.

**Deep learning used in Mars missions:**

Convolution neural network (CNN) is a most significant algorithm designed to deal with image processing tasks. CNN algorithm is developed by convolution layers to identify the features in the image these networks can identify objects, features, and patterns in images for classification, object detection, and segmentation.

Additionally, GNN and RNN are used. RNN is used to process video and images captioning. RNN will process the sequential data and it can use in a sequence of images which is generated by telemetry, weather, and atmospheric data. GNN is used to image editing and image generation. It has two types of generator networks and discriminator networks.

**CNN model in Mars Rover Mission- Soil Property and Terrain classification:**

This process involves identifying the terrain conditions to check whether that rover or lander can land safely in a particular place to navigate the environment. The model creates a map of the terrain, classifying it based on properties trained by previous data. Which is necessary for space missions to avoid obstacles. Deep learning has increased the accuracy of traverse analysis by using convolution neural networks to analyze 3D points. The models learn from data to which place is traversable. Another approach involves increasing the accuracy of the model in identifying the images.

**New techniques for CNN**

GAN is the latest advanced technique used to generate realistic synthetic images of Mars. It is used to analyze real-world images over a period.

Ongoing research on Reinforced learning implementation for decision-making for rocks detection and classification of Mars images captures by the rover.

**Slip Prediction**

The analysis is to identify the traction loss that can happen between the rover wheel and the slip surface. This slip can be analyzed by images sent by rover’s camera. The model is trained on images that are captured sequentially while the rover is in motion and on other missions. CNN is used to predict slips of vehicles. Due to multiple layers and pooling operations, it calculates the slip with MSE and is optimized by gradient descent. The model is able to predict slip with a 0.75 correlation coefficient.

**Challenges**

* The Mars rover mission is one of the most important scientific achievements of the space exploration mission.
* The major challenge faced in this mission was roughness and unable to predict the terrain. The traversability analysis is a critical part of this mission which helps to navigate and explore the planet. 2. The convolution neural network approach can be able to classify it into three types they are traversable, partially traversable, and non-traversable. It is done by training and testing the Mars exploration rover on images of the data set.
* The results show how deep learning models outperformed traditional machine learning algorithms such as support vector machines and decision trees. The pre-trained models on the mission were performed with good accuracy.
* The slip component is another issue of traversability analysis. It will analyze the slope and texture of the terrain to predict the slip by using CNN.

**Limitations**

* The deep learning model can classify terrain and improve in predicting the slip of terrain with good accuracy. But they have some limitations, for developing the deep learning model we need a large amount of data but availability is high cost and limited.
* While classifying the terrains the model is able to train on one data and one region so it may not be able to generalize well in different regions and different terrains.
* The models are computationally expensive; they need high-performance computers for computing. Which is challenging to implement and deploy a deep learning model.
* The models can be difficult to interpret data and make decisions.

**Solutions:**

* Limited data availability can be solved by data augmentations techniques of rotation, scaling, and translation to increase data availability for training.
* By using the fine-tuning pre-trained models on large datasets.
* Creating ensemble models to improve model performance which can prevent the model from overfitting and increase the model reliability of the predictions
* Developing hybrid models like combining the deep learning models with rule-based and including physics can help in overcoming the models
* Using high-performance GPUs, FPGAs, and ASICs to increase the computation efficiency of models.
* Using sensors like radar and cameras to improve the accuracy and perception capabilities of the rover.

**Conclusion:**

Deep learning techniques have been widely used in Mars missions, especially for terrain classification and slip prediction. The Curiosity Rover mission faced challenges with limited computational resources and difficulties in feature extraction, but it still managed to implement deep learning models with some success. It helped to create more accurate classifications most advanced techniques reduced the limitations of earlier models. These techniques have enabled the rover to perform more accurate terrain classification and slip prediction, leading to better navigation and increased scientific data collection. While deep learning has been instrumental in these Mars missions, there are still limitations such as the need for large amounts of training data, potential overfitting, and limited interpretability of the models.

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