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Synthetic Aperture Radar Image Classification Using Deep Learning

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Abstract:- Powerful remote sensing tools like Synthetic Aperture Radar (SAR) can detect targets and classify land cover, as well as give useful data for monitoring disasters and other uses. Different Deep Learning processes have made a remarkable changes in the past few years, in terms of precision and effectiveness of SAR picture classification. To improve the precision and dependability of SAR picture interpretation, this research paper presents a thorough investigation of SAR image categorization utilising deep learning techniques, such as convolutional neural networks (CNNs) and recurrent models. We review the state of the art now, suggest a fresh approach, and indicate potential future research possibilities. Our findings show that deep learning is excellent at classifying SAR images, laying the groundwork for more advanced remote sensing applications.

Keywords:- *SAR, Deep Learning(DL), CNN.*

I. INTRODUCTION

Synthetic Aperture Radar (SAR) has been used for remote sensing for Earth, for over 40-45 years. The first successful in 1964 by Jet Propulsion Laboratory. SAR gives high-resolution, day and night and weather independent images for multiple different applications that range from geographical science and climate change researches to Earth system monitoring and environment, 2-D and 3-D mapping, detection in change, security-related applications up to very different from one another. Radar aperture is another word used for the antenna on the space let in light. Radar aperture uses electromagnetic waves as a medium. Radar in SAR is an acronym for radio Detection and Ranging. [1]

A. Working of SAR

SAR : remote sensing technology that make use of radar to create high resolution images of the Earth's surface. It works by transmission of microwave signals towards the target areaand then receiving the signals that are reflected. A simplified explanation of how SAR works can be said as follows :

- Transmission of Radar Signals: SAR systems are typically mounted on satellites, aircraft, or other platforms. These generate microwave signals, bands that are emitted towards the ground.
- Signal Reflection: These radar signals interact with objects and the terrain on the Earth's surface. When the signals encounter an object or a change in the surface, such as a building, a tree, or the ground itself, some of the energy is bounced back towards the SAR system.
- Receiving Signals: The SAR system has a sensitive antenna that collects the reflected signals, which are often referred to as "backscatter."
- Measurement of Time Delay: SAR systems measure the time it takes for the transmitted signal to travel to the target and back. By knowledge of speed of light, these calculate the distance to the objects on the Earth's surface.
- Synthetic Aperture: Unlike traditional radar, SAR has a synthetic aperture, which is created by moving the radar antenna along a known path. As the platform (e.g., satellite) moves, it collects radar data from different positions. This motion effectively creates a larger antenna, allowing for the formation of high-resolution images.[2]
- Data Processing**:** The raw radar data collected from multiple positions is then processed to create a coherent image. Complex algorithms are used to account for the different positions of the antenna, the time delays, and the phase differences in the received signals.
- Image Formation**:** The processed data is used to construct a detailed and high-resolution image of the Earth's surface. This image can reveal features such as buildings, vegetation, water bodies, and terrain with a high level of detail. [3]

B. Applications of SAR

Due to the formation of high-resolution imagery Sar is widely used in different fields, SAR has many applications, including but not limited to:

- Environmental Monitoring: Sar is used to map land and land coverage. Deforestation and monitor forest. Monitoring of crop and crop classification and yield estimation. Soil moisture and subsidence monitoring. Detection of land and coastal changes. Glacier monitoring and ice sheet studies.
- Disaster Management and Response: Detection and monitoring of natural calamities for example earthquakes, floods, and landslides. Damage estimation and assessment done by disaster in affected areas. Monitoring of volcanic eruptionsand ash cloud tracking. Detection of oil spills and monitoring its spread

- Urban Planning and Infrastructure Monitoring: Analysis of Urban growth and planning. Monitoring infrastructure such as roads, bridges, and buildings for deformation and structural integrity. Identification of illegal constructionand urban sprawl.
- Coastal Applications: Ship detection and vessels for maritime surveillance. Monitoring of sea ice, currents, and oil spills in oceans. Coastal zone management, including erosion and land subsidence monitoring.
- Agriculture and Forestry: Monitoring of crop health, growth, and disease outbreaks. Forest inventory and canopy height estimation. Assessment of deforestation and illegal logging activities.
- Archaeological and Cultural Heritage Preservation: Identification of archaeological sites and buried structures. Monitoring and preservation of historical monuments and cultural heritage sites.
- Military and Defence: Reconnaissance and surveillance of enemy territory. Detection and tracking of moving targets, including vehicles and personnel. Mapping of terrain and assessment ofthe battlefield.
- Geological Exploration: Detection of underground geological structures. Identification of mineral deposits and resources. Assessment of geological hazards like fault lines and sinkholes.
- Scientific Research: Studies of Earth's crustalmovements and tectonic plate dynamics. Monitoring of environmental changes in remote and inaccessible areas. Research on climate changeand its impacts.
- Search and Rescue Operations: Detection of distressed ships or aircraft at sea. Locating missing persons in wilderness or disaster-stricken areas
- Weather Forecasting: Monitoring and tracking severe weather phenomena such as hurricanes and typhoons.[4]
- Infrastructure Planning and Development: Planning transportation networks, including road and railway construction. Monitoring construction activities and infrastructure projects.

II. LITERATURE REVIEW

S. No.	Authors	Year	Research Objective	Methodology	Key Findings
1.	Hasan Anas, Hani Majdoul, Anibo Chaimae,and Said Mohamed Nabil1.	2020	Classification methodapplied to synthetic aperture radar (SAR).	They applied a CNNmodel (VGG 16) forfeature extraction ofSAR images. Used MSTAR as dataset.	Final Accuracy:97.91%
2.	A. Pasah, S. N.S., B. Paul and D. Kanda	2022	Investigate and analyse the use of deep learning techniques in the classification of Synthetic Aperture Radar (SAR) images.	Comprehensive review and analysis of existing techniques for SAR classification using deep learning.	The key findings highlightthe State-of-the-Art Methods, Architectures and Configurations, Issues in SAR ImageProcessing, Misclassification and potential future models.
3.	Pia Aabo, MariLuca Berardi, Filippo Biondi,Marta Citile, Carmine C., Nicomino F., Gaetano G., Danil Olando, Linjie Yan	2023	The research objectiveof this study is to address the challenge of spatial resolution improvement in Synthetic Aperture Radar (SAR) imagery.	The methodology involves the exploration and assessment of different approaches to SAR super-resolution, including sparsity, compressive sensing, anddeep learning (DL).	The key findings highlightthe development of the DC2SCN architecture, its ability to process complex SAR data while preservingboth amplitude and phase information
4.	Alicia Passah, Debdatta Kandar	2023	The study aims to develop a lightweightdeep learning model that aims to increase the accuracy by scaling down the parameters up to 25 times.	The methodology involves the assessmentof deep learning modelsand development of a lightweight model.	The key findings include evaluation of deep learning models, observations and comparisons and proposed lightweight deep learning model.

III. METHODOLOGY

A. Working of CNN Model

- A DL method also called convolutional neural network (CNN) is most effectual in processing and conceding images.
- This structure is composed of connected layers, pool layers, and convolutional layers.
- The significant part of a CNN is its convolutional layers, where filters are used in extraction of properties like textured and angles to form with the input image.
- Convolutional layer output is then sent through a variety of pooling layers, which are used to downscale feature maps and extract the most important information while reducing the spatialdimensions.

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- The output of the pooling layers is then applied to one or more fully connected layers to forecast or categorise the image.[5]
- Unsupervised learning techniques can be used when working with unlabeled data. Using autoencoders is one of the most well-liked methodsfor accomplishing this.
- As a result, you can conduct computations in the initial section of CNN while fitting data into a space with few dimensions.
- After doing this, you must reconstruct using additional layers that up-sample the data you already have.

Convolutional Neural Networks (CNNs) work by utilising several operations and layers to input data, typically images, to automatically learn and extract features and patterns at different levels of abstraction. Here's how CNNs work in more detail:

- Input Layer : An image (or a stack of images) is theinput to a CNN. A grid of pixel values serves as an image's representation.
- Convolutional Layers: The convolutional layer is the foundation of a CNN. Within this layer, small filters (also called kernels) slide or "convolve" over the input image. Each filter detects specific features or patterns (edges, textures, shapes) by performing element-wise multiplications and summations.
- Activation Function: After convolutional, there is an activation function (typically “ReLU - Rectified Linear Unit”) is used element-wise to enter non- linearity. This helps the network learn complex patterns and relationships.
- Pooling Layers: The pool layer is the next layer. This shrinks the sample size for a specific feature map, or down samples it. Additionally, by lowering the number of parameters the network must process, processing becomes significantly faster. The result of this is a map with a pool.
- Fully Connect Layers: After several convolutional and pooling layers, one or more thick layers that are entirely connected are typically added. These layers flatten the high-level features and perform classification or regression tasks.
- Learnable Parameters: All layers of the CNN have learnable parameters. The convolutional layers have filter weights, and the fully connected layers have weights and biases. During the training phase, these parameters are learned via backpropagation and optimisation methods like gradient descent.
- Loss Function: A loss function calculates the discrepancy between the target and the expected output (ground truth).
- Backpropagation: The parameters of the network are updated in the opposite direction using the gradients of the loss with respect to the parametersof the network.
- Training: CNNs are trained on a labelled dataset. The network learns to recognize features that are relevant to the task it's designed for. For example, in image classification, it learns to recognize features that distinguish different objects or categories.
- Inference: After training, the CNN can make predictions on new, unseen data. It passes the input through the layers, and the final layer's output represents the network's prediction.

IV. ISSUES AND CHALLENGES

After studying and reviewing different literature on the application of SAR images. One major problem is faced by many users is the availability of labeled SAR training data and that too with high resolution. The biggest dataset that is available for free use is MSTAR dataset but that only contains limited military features. Many researchers have created their own unique style to combine available data but that turns to be expensive. There are many techniques that can be applied to increase the efficiency but a reasonable dataset is required.

V. FUTURE SCOPE AND CONCLUSION

This paper provides the most recent deep learning-based SAR image classification using deep learning. In many practical scenarios, the classification of SAR images is the crucial final step in their interpretation. Given the remarkable progress obtained using deep learning in a variety of computer vision tasks, we conducted an investigation into the latest exclusive approaches utilizing deep learning techniques for SAR image perception. This investigation shed light on the specific architectural choices made in each method, as well as the configurations and parameters employed. Nevertheless, a pressing challenge associated with SAR image classification is the occurrence of misclassifications. This issue remains unresolved, and addressing it is of paramount importance, as the misinterpretation of targets can result in misinformation in real-world applications. Our study also delved into the strengths and weaknesses of each of these approaches, providing a comprehensive overview. In the future expansion of data set is required with more labelling of dataset.[6]

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