"High Resolution Satellite Imagery Analysis for Terrain and Surface Data Extraction: Techniques and Applications"

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ABSTRACT :

With multiple applications and use cases of digital elevation models (DEMs), focusing significantly on forming 3D models. It is used in various research areas such as flood modeling, agriculture, satellite navigation, farming, and forestry. Dems required are mainly of high resolution and quality to achieve maximum accuracy thus giving us accurate elevation. In this context, one of the major research areas is the extraction of DEMs from high-resolution satellite imagery. There are three different techniques to generate the DEMs[1]. Traditionally photogrammetry was developed, LIDAR[5] is the second method, last and the most recent technique is an interferometric synthetic aperture radar (InSAR)[3]. The development of Artificial intelligence(AI) and machine learning(ML) has experienced tremendous growth in recent years and therefore made it easy to develop multiple algorithms that can help us in processing. In our project, we have used the Deep learning(DL) approach to preprocess the satellite image and thereby form a segmented, RGB image. In addition, the latest improvements in both software and hardware have made it possible to carry the processing with remarkable speed, even on moderately powerful hardware. We anticipate that our research will act as a catalyst for further advancements and will facilitate the integration of this research in generating, updating, and analysis of DEMs.

Keywords : Digital Elevation Model, LIDAR, InSAR, Phogrammetry, etc.

1. INTRODUCTION :

The availability of many Satellite images has given rise to applications in various fields and hence increased the potential of dem extraction. The DEM[10] is a 3D representation that provides information about the height of the ground, vegetation, or any other object above the ground level. This model exclusively records data related to the altitude of geological features, rendering it a representation of the "bare earth." The DEM comprises two distinct models - the Digital Terrain Model, which represents the surface of the earth and provides elevation data while excluding any other features like vegetation and buildings, and the Digital Surface Model, which includes all-natural and man-made objects found on the earth's surface along with the earth's surface, it also captures the ground features. Among the high-resolution satellites used to capture images which are later used for dem extraction, IKONOS has a broad range of applications, which spans urban and rural mapping of natural resources and natural disasters, and change detection. It can provide valuable insights into nearly all aspects of environmental study. Quickbird. The QuickBird satellite acquired high-resolution image data with a degree of detail of 0.65m pixels. Due to its outstanding imaging capabilities, the satellite was employed in diverse fields, including agriculture and forestry, with environmental studies being a particularly significant area of application. The images obtained from high-power satellites are complex and challenging to analyze and interpret manually. Therefore, artificial intelligence(AI) and machine learning(ML) techniques are necessary to facilitate the mapping process. Deep Learning (DL) is the data-intensive version of ML that has proven to be useful for various difficult tasks such as natural language processing, computer vision, reinforcement learning, and others.

2. MODELS AND METHODOLOGIES :

2.1 Overview of the elevation models :

2.1.1 Digital Elevation Model (DEM) :

Digital Elevation Model, also known as a DEM is most important technique that is used for digital imagery of elevation. Digital Elevation Model describes the 'elevation' of the ground surface, as can be seen in Figure.1, vegetation or any other objects above the ground. In short, when we cut out the non-ground points then we get smooth digital elevation model.

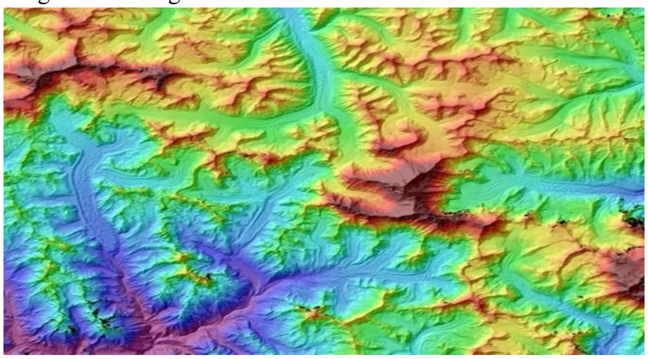

Figure. 1 Digital Elevation Model (DEM)

DEM can be represented using two different models: Digital Terrain Model (DTM)[2] and Digital Surface Model (DSM) as represented in Figure. 2.

2.1.1.1 Digital Terrain Model (DTM):

Digital Terrain Model generally refers as a representation of the Earth's Surface. Digital Terrain model elevation is done when we exclude the features like vegetation, buildings, bridges, etc.

2.1.1.2 Digital Surface Model (DSM):

Digital Surface Model[8] represents the 3D representation of the height of Earth's surface, including natural and man-made objectives. Digital Surface Model captures both the natural and artificial features of the environment. Digital Surface Model represent the earth's surface and all of its above- ground features.

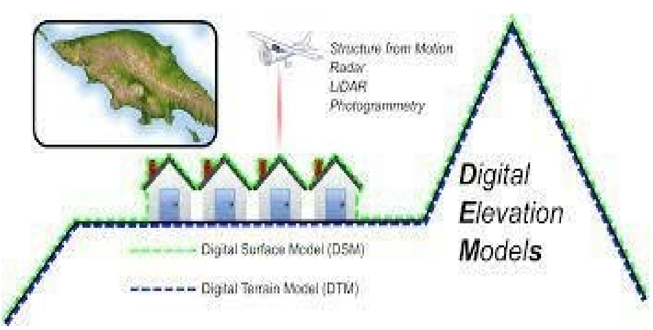

Figure 2. DEM, DTM and DSM elevation models

2.2 Different techniques for object detection:

DEM (Digital Elevation Model) data is generated using a variety of techniques as shown in Figure. 3, which include:

2.2.1 LIDAR:

Light detection and ranging (LiDAR) basically uses electromagnetic energy in the optical range to detect an object. It also determines the distance between the targets and thus is a useful to calculate the elevation from a satellite image. LIDAR uses laser light to measure the time for reflected light to return back to receiver after targeting the surface with laser light. LIDAR maps can be used to give positional accuracy, to allow data scientist to know where in the world the data was collected and how every point on relates to objects terms of distance.

2.2.2 PHOTOGRAMMETRY:

It uses photographs and views the same photograph from two different points, it helps us obtain different depth and outlook because of separate points of observation. In science and technology the method of obtaining information about the environment using photographic images. It is a threedimensional coordinate measuring techique that uses photographs for measurement. Aerial photogrammetry[6] is technically a subset of remote sensing that involves visible light spectrum waves in the EM spectrum.

2.2.3 SATELLITE INTERFEROMETRY:

Synthetic aperture radar (SAR) uses two radar images from antennas captured at the same time to create DEM. SAR refers to an active data collection technique where an active sensor sends its own energy in the form of signals to produce high-resolution image. In SARS a sequence of data captured by small antenna is combined, to simulate a larger antenna, giving us a high spatial resolution image. Signal wavelength is used to calculate how far a signal can penetrate in a medium and how radar signal is interacting with the surface.

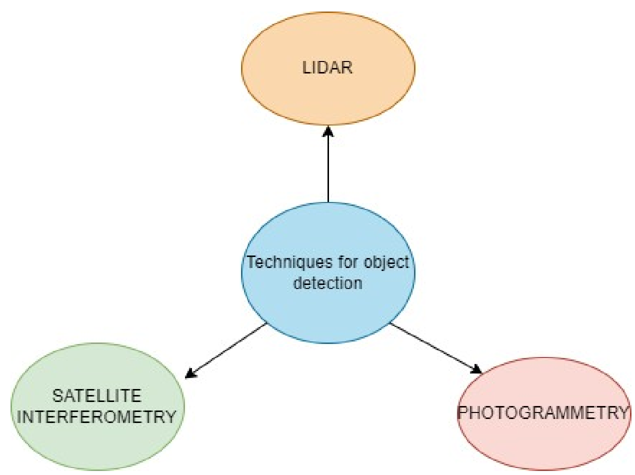

Figure 3. Different techniques for object detection

3. SATELLITE IMAGE PREPROCESING TECHNIQUES IN REMOTE SENSING :

3.1 CNN :

CNNs[7] (Convolutional Neural Networks) have a broad range of uses, from voice recognition and facial recognition to image processing and nearly all computer vision tasks. These networks function by mapping features, using a technique that involves backpropagating results through various layers, including pooling layers, convolutional layers, and fully connected layers, as mentioned in Figure.4. The three key ideas of CNNs identified by Goodfellow et al. One approach involves utilizing small feature detectors to identify edges within an image, particularly in cases where the image is large, such as satellite imagery. This technique, referred to as "sparse interactions," aims to overcome the challenge of detecting edges in such images. Another strategy is to implement "parameter sharing," which helps manage the number of weights required for processing an input image. By reducing the number of parameters, this technique can significantly decrease the computational power needed. lastly "Equivariant representation" implies that object detection remains unaffected by variations in illumination and changes in position, while the internal representation of the detected object remains equivariant to such alterations. By utilizing these points, we can overcome the challenge of processing large satellite images that are difficult to manage in their original dimensions. This operation involves only a minimal number of parameters, streamlining the training process and accelerating the network's performance.

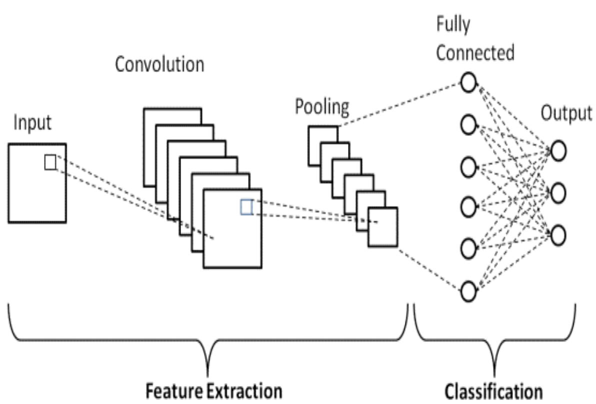

Figure 4. CNN Architecture

3.2 Methods for satellite image processing :

Satellite image processing involves several techniques and algorithms to analyze the data captured by satellites. Some of these methods include image enhancement, feature extraction, segmentation, fusion, change detection, compression, classification, and feature detection shown in Figure. 5.

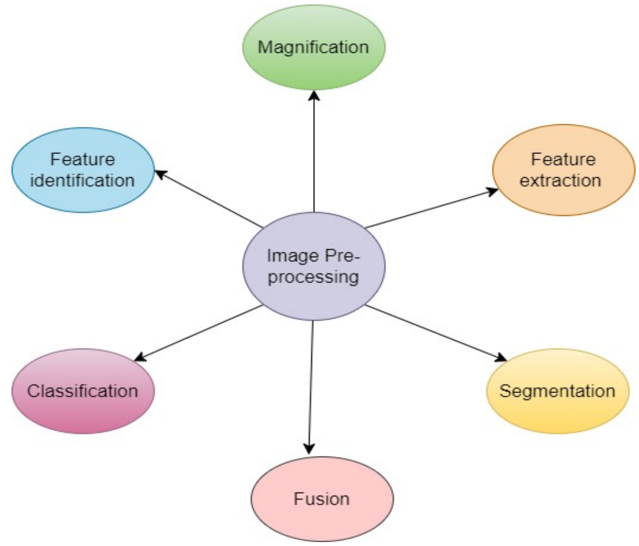

Figure 5. Different methos for satellite image processing

Now let us see all the image pre-processing frameworks in detail.

3.2.1 Image magnification method :

Brightness level of images from satellite being low, hence image magnification is one of the important tasks to be performed. There are different methodologies developed in order to make the image clear and solve the low brightness level problems. Image magnification is the first step, later comes the other preprocessing techniques i.e. segmentation, object detection, etc.

In order to employ image magnification, it is essential to comprehend the nature of the image or problem being addressed, specifically in terms of the underlying factors such as detail, color, and lighting. It is important to note that not all methods of image enhancement will yield satisfactory results. Therefore, it is imperative to predict which image enhancement method will be required in order to achieve the desired outcome.

3.2.2 Feature extraction method :

Feature extraction is an important step used in generating new features for the further tasks of classification. These newly generated features help us in achieving greater accuracy in classification. These features can be broadly divided as general and domain specific ones.

3.2.3 Image segmentation method :

Division of the satellite image into various segments such as building, land, road, vegetation, water and unlabelled is done in this phase, shown in Figure 6. Numerous algorithms are available for semantic segmentation[4], including Feature Pyramid Network (FPN), Mask R-CNN, U-net, and more. In this context, the primary emphasis will be on U-net[9], which is a widely recognized image segmentation algorithm that shares many concepts with other algorithms. U-net focuses on addressing the issue of localizing and differentiating borders by performing pixel-level classification, allowing for input and output to have the same size. The architecture of U-net comprises an encoder network followed by a decoder network.

Figure 6. Semantic Segmentation

3.2.4 Fusion :

In this phase we combine two or more images to form a new image which has more features giving better accuracy. It is done using certain algorithms in order to create a image that gives more accurate information. Application of this method includes finding the correlation between the images that we have combined and the image that is newly formed, hence giving us the varying features. A technique known as Bayesian method is used to combine these images and improve the resolution of the new image. One limitation of this method is the noise that is present, supposedly we have noise in the images that we ought to combine than it results in the newly formed image being not so efficient.

3.2.5 Classification Method :

Given below is the overview of the steps included in the classification process.

3.2.5.1 Read large images and corresponding masks, divide them into smaller patches. And write the patches as images to the local drive.

3.2.5.2 Save only images and masks where masks have some decent amount of labels other than 0. Using blank images with label=0 is a waste of time and may bias the model towards unlabeled pixels.

3.2.5.3 Divide the sorted dataset from above into train and validation datasets.

3.2.5.4 You have to manually move some folders and rename them appropriately if you want to use ImageDataGenerator from keras.

3.2.6 Image Feature Identification :

Availability of large amount of aerial imagery and advancements in deep learning techniques have collectively led to the successful preprocessing of the images along with various use-cases. This method helps us in understanding all kinds of features used in information extraction.

4 CONCLUSION :

In conclusion, UNet is an effective method for DEM extraction from satellite images due to its ability to handle complex image data and extract high-resolution features. By utilizing a deep convolutional neural network architecture, UNet can learn complex relationships between the input image and output DEM, resulting in accurate and detailed elevation data. UNet-based DEM extraction can also be automated, reducing the need for manual intervention and increasing efficiency. However, UNet may still encounter challenges with noisy or low-quality images, and further research is needed to optimize the model for different scenarios. Overall, UNet offers a promising solution for DEM extraction from satellite imagery, with potential applications in various fields such as geology, urban planning, and environmental monitoring.

5 FUTURE SCOPE:

Low contrast satellite images, misinterpretation of image pixels and improper threshold selection for image segmentation are some of the major challenges in image processing. Satellite images are very complex to preprocess but the advancements in machine learning and deep learning techniques has helped us in extracting useful information from aerial imagery and make the decisions effectively. We can apply the mentioned techniques on real time satellite imagery and use the remote sensing techniques for further use of various algorithms and hence get better accuracy.

6 REFERENCES :

[1] Uysal, M.; Toprak, A.S.; Polat, N. DEM Generation with UAV Photogrammetry and Accuracy Analysis in Sahitler Hill. Measurement 2015, 73, 539–543. [Google Scholar] [CrossRef]

[2] Arefi, H., dAngelo, P., Mayer, H. and Reinartz, P., 2009. Automatic generation of digital terrain models from cartosat-1 stereo images.

[3] Burkhart, G.R., Z. Bergen, R. Carande, W. Hensley, D. Bickel, and J.R. Fellerhoff, 1996. Elevation correction and building extraction from interferometric SAR imagery, Proceedings of IGARSS'96, Lincoln, Nebraska, I, pp. 659–661.

[4] Anurag Arnab and Philip HS Torr. Pixelwise instance segmentation with a dynamically instantiated network. In CVPR, 2017. 1, 3, 8

[5] Arefi, H. and Hahn, M., 2005. A morphological reconstruction algorithm for separating off-terrain points from terrain points in laser scanning data. ISPRS.

[6] S. Siebert et al. Mobile 3D mapping for surveying earthwork projects using an Unmanned Aerial Vehicle (UAV) system Autom. Constr. (2014)

[7] Rozenwald MB, Galitsyna AA, Sapunov GV, Khrameeva EE, Gelfand MS. A machine learning framework for the prediction of chromatin folding in Drosophila using epigenetic features. PeerJ Comput Sci. 2020;6:307.

[8] A Julzarika and Harintaka 2020 IOP Conf. Ser.: Earth Environ. Sci. 535 012034

[9] X. Li, H. Chen, X. Qi, Q. Dou, C. -W. Fu and P. -A. Heng, "H-DenseUNet: Hybrid Densely Connected UNet for Liver and Tumor Segmentation From CT Volumes," in IEEE Transactions on Medical Imaging, vol. 37, no. 12, pp. 2663-2674, Dec. 2018

[10] DPanagiotou, E.; Chochlakis, G.; Grammatikopoulos, L.; Charou, E. Generating Elevation Surface from a Single RGB Remotely Sensed Image Using Deep Learning. Remote Sens. 2020, 12, 2002.

[11] Omprakash Tembhurne, Deepti D. Shrimankar "FC-TLBO:Fully Constrained Meta-Heuristic Algorithm for Abundance Estimation using Linear Mixing Model". In: ADHANA (SCIE) 42 (7), pp. 1123–1133.

[12] Omprakash Tembhurne, Deepti D. Shrimankar, "N- SO:End-member extraction using advance particle swarm optimization for NLMM". in: SADHANA (SCIE) 43 (9), pp. 141–156.

[13] Omprakash Tembhurne, Sonalli Milmile et.al (2022, eptember). "An Orchestrator A Cloud-Based Shared-Memory Multi-User Architecture for Robotic Process Automation". In: International Journal of Open Source Software and Processes(SCOPUS) 13 (1), pp. 1–17.

[14] Prashant Satpute, Omprakash Tembhurne. "A review of Cloud centric IoT based framework for supply chain management in precision agriculture". In: International Journal of Advance Research in Computer Science and Management Studies 2 (11).

[15] Yogesh Shinde, Omprakash Tembhurne, "A Review of Protect the Integrity of Outsourced Data Using Third Party Auditing for Secure Cloud Storage". In: International Journal of Advance Research in Computer Science and Management Studies 6 (2).