Satellite Image Classification and Analysis using Machine Learning with ISRO LISS IV

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Abstract - For several years, detecting objects in satellite imagery has been a difficult task. Higher accuracy in the identification of different artifacts from very high-resolution satellite images has been achieved thanks to the creation of successful machine learning algorithms and advancements in hardware systems. Satellite imaging has been successfully used for weather forecasts and spatial and geological purposes over the last few decades. For these types of applications, low-resolution satellite images are adequate. In our project, high-resolution images will be used where the prediction is done by processing their images and producing respective valid data for the same. The high-resolution satellite images are being provided by RRSC- C ISRO,Nagpur. For autonomous systems to interact with their environment intelligently, they must be given the ability to adapt and learn incrementally and deliberately. This project focuses on extracting and identification of objects from the high-resolution satellite images which will be provided as an input from the satellite to extract the features of the image which are then converted into machine valid data. This valid data is then fed to the neural network model. The neural network model analyzes each image and classifies it with the feature label. This will generate the output screen which displays the extracted feature from the original image which is given as input to the system.

Keywords: Image Classification, Machine Learning, CNN, Supervised Technique, Support Vector Machine.

I. Introduction

Image classification is an important part of remote sensing, image analysis, and pattern recognition. In some instances, the classification itself may be the object of the analysis. For example, the classification of land use from remotely sensed data produces a map-like image as the final product. Image classification, therefore, forms an important tool for the examination of digital images. At present, there are different image classification procedures used for different purposes by various researchers. Over the last decade, remote sensing technologies are available easily and in abundance. Recently remote sensing images are being used widely for urban area classification and change detection. Classification is used for various applications like Crops, Cars, Roads, Trees, Struct, Buildings, Healthy water, Wastewater, Railway routes, and Trucks. The selection of a suitable classifier to process the satellite images has an important role in the efficient and accurate classification results. In this work, we are creating a system to classify satellite images to extract information using image processing techniques. Classification of satellite images into used and unused areas and also sub-classing of each of the classes into four different classes has been carried out. Used satellite images are further classified into residential, industries, highways, croplands, and unused images. Manual classification by using image interpretation techniques requires more time and field experts. So in our work, we focused on efficient automatic satellite image classification. Convolutional neural networks are used for feature extraction and classification of satellite images.

CNN is a deep neural network that is most suitable when we deal with images. CNN will help to provide higher classification accuracy. A confusion matrix is used to estimate the overall classification accuracy. Deep learning is a class of machine learning models that represent data at different levels of abstraction utilizing multiple processing layers. It has achieved astonishing success in object detection and classification by combining large neural network models, called CNN with powerful GPU.

CNN-based algorithms have dominated the annual ImageNet Large Scale Visual Recognition Challenge for detecting and classifying objects in photographs. This success has caused a revolution in image understanding, and the major technology companies, including Google, Microsoft, and Facebook, have already deployed CNN-based products and services. Satellite image classification is the most significant technique used in remote sensing for the computerized study and pattern recognition of satellite information, which is based on diverse structures of the image that involve rigorous validation of the training samples depending on the used classification algorithm. It is an extreme part of remote sensing that depends originally on the image resolution, which is the most important quality factor in images. Image Classification or segmentation is a partitioning of an image into sections or regions.

The power of such algorithms depends on the way of extracting the information from the huge amount of data found in images.

Machine learning is the scientific study of algorithms and statistical models that computer systems use to perform a task without using explicit instructions, relying on patterns and inference. In our program, machine learning algorithms are applied to achieve image processing. In ISRO, to perform image processing the scientists have to first convert the image into data frames and feed this information into a system application where manually they have to change the bands depending on the image and identify objects in the image. This process is time-consuming and sometimes can lead to errors as the data is not precise which can lead to inaccurate processing of the data. Ourproject builds a system that can identify the number of bandsof the image and create precise data that can be fed to the system this data is then processed using the concept of a convolutional neural network to obtain feature extraction and object recognition without any manual effort. The primary concept of the project is to focus on the information which willbe obtained by processing the images or datasets that are made available from the sensor. The sensor that is used for our project is LINEAR IMAGE SELF SCANNING SENSOR – IV, also known as LISS-IV. The images on the satelliteare captured by the sensor which takes high-resolution images. The high-resolution satellite images are being provided by RRSC- C ISRO, Nagpur.

Problem Statement:

To segment and detect the images received from satellites by using a deep learning system and image processing which classifies objects and facilities in high-resolution multispectral satellite imagery.

II. Review Of Literature

A literature review is an evaluative report of information found in the literature related to your selected area of study. The review is written so that it should give a theoretical base for the research and help you to determine the nature of your research. When conducting research, a literature review is an essential part of the project because it covers all previous research done on the relative problem statements and sets the platform on which the current research is based. No new research can be taken seriously without first reviewing the previous research done on the topic. The current research workis a literature review on satellite image processing methods and techniques based on the given problem statement. It describes and provides details on various satellite image classification methods to the analyst. The current literature review emphasizes automated satellite image classification and algorithmic methods and techniques used for processing. Our research focuses on finding and surveying different ways to extract features of objects which can be used as fixed parameters to classify objects with the help of C- 2S and Liss - IV irrespective of the color of the image being given as input, & in our survey, we found several papers which gave details about different methods which are being used already for this purpose. In our survey, we found that the best way to classify objects in an image is by converting the images into different bands and using them to identify the objects to achieve our goals. The conversion of bands can be achieved by using python scripts and then providing the converted image as input to the trained machine which will be able to process the image received from the satellite and complete the task assigned to us based on image processing with the help of Liss - IV.

Literature Survey

Remote Sensing [1] is a technique introduced in the early 1960s for data analysis and interpretation. Remote sensing collects a hugeamount of satellite data. Satellite remote sensing imagery covers a large geographical area with high temporal frequency as compared to other imagery. Interpretation of these satellite images helps in a variety of applications such as environmental conservation and management, water resource research, soil quality studies, environmental study after natural disasters, meteorology simulations, deriving land use and land cover information, and preventing natural disasters, studying climatic change evolution. Different techniques are used for data extraction from remote sensing images. The classification techniqueis the most useful technique for image interpretation and information extraction [2]. Satellite image classification groups together the pixels of the image into several different defined classes [3]. The pixels are grouped based on the digital values extracted from the satellite images. The pixelvalues extracted from the satellite images could be a single value as in the case of grayscale images or a multivariate value for the multispectral, temporal or multi-modal image. The classification helps in extracting the information contained in different bands [4] of the satellite sensor and the information is extracted in terms of digital numbers which are then converted to a category. S. Muhammad et al., [5] proposed a supervised satellite image classification method using the decision tree technique. This method extracts features from satellite imagesbased on pixel color and intensity. Extracted features assist to determine objects that reside in the satellite images. The method classifies satellite images using a decision tree with the support ofidentified objects. In the paper, "Very High-Resolution Satellite Image Classification Using Fuzzy Rule-Based Systems", J. Shabnam et al. [6] introduced a supervised satellite image classification method to classify very high-resolution satellite images into specific classes using fuzzy logic. This method classifies satellite images into five major classes: shadow, vegetation, road, building, and bare land. This method uses image segmentation and fuzzy techniques for satellite image classification. It applies two levels of segmentation, first-level segmentation identifies and classifies shadow, vegetation, and road. Second level regions. Fuzzy techniques are used to improve the classification accuracy at the borders of objects. “Land Cover Classification of Satellite Images using Contextual Information” by Bjorn Frohlich [7] Presents a method for the classification of satellite images into multiple predefined land cover classes. This method is automated and uses segment-level classification with the support of a training set. The classification methods include contextual properties of predefined multiple classes to improve classification accuracy. In the paper "Spatial technique for Image Classification" [8] Selim proposed a classification method using the Bayesian technique. The method uses spatial information for the classification of high-resolution satellite images. The method performs classification in two phases. Phase 1: spectral and textural features are extracted for each pixel to train Bayesian classifiers with discrete nonparametric density models. Phase 2: the iterative split-and-merge algorithm is used to convert the pixel-level classification maps into contiguous regions. "Comparison of Four Classification Methods to Extract Land Use and Land Cover from Raw Satellite Images for Some Remote Arid Areas, Kingdom of Saudi Arabia" [9] on ISODATA technique is the most common unsupervised satellite classification method. It creates a predefined number of unlabeled clusters/classes in a satellite image. Later meaningful labels are assigned to the clusters. ISODATA parameters need several parameters that control the number of clusters and iterations to be run. In a few cases, clusters may contain pixels of different classes. Support Vector Machine (SVM) [10] is a non-parametric unsupervised statistical classification method. This method can be used to extract land-use maps. SVM works on the assumption that there is no information on how to distribute the overall data. SVM reduces satellite classification cost, increases speed, and improves accuracy Maximum method is a statistical supervised approach for recognizing the patterns. It allocates pixels to appropriate classes based on the probability values of the pixels [11]. Maximum likelihood is an efficient method to classify pixels of the satellite image. But it is time-consuming and insufficient ground truth data produces poor results. The paper, "Fundamental of Remote sensing" by George joseph [12] also gives a brief idea about the mechanism involved in capturing satellite imagery in various bands and storing it in a different format. We have also referred Giss website [13] for basic concepts of satellites, sensors, and information on remote sensing. It gives the basic mechanism which is involved in remote sensing. This website also gives a brief description of various formats of images.

Architecture Overview:

A CNN consists of a series of processing layers as shown in Fig. Each layer is a family of convolution filters that detect image features. Near the end of the series, the CNN combines the detector outputs in fully connected “dense” layers, finally producing a set of predicted probabilities, one for each class. The network itself learns which features to detect, and how to detect them, as it trains.

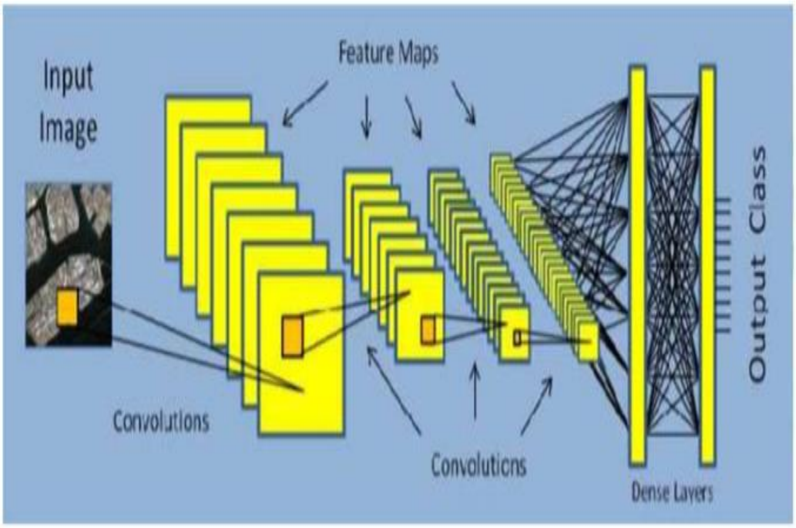


Figure. The architecture of Satellite Image classification.

IV. Data Analysis

The train_wkt.csv file comprises three columns. The first one consist of the Image Id which is equivalent to the name of the Image file. Image Id for all the individual images of the training dataset is unique so while training the model it doesn't get conflict. The second column name is Class Type, which consists of the type of object which is present in the class whether the defined body is a water body, building or cropland, etc. The Class Type is denoted by the number between 1 to 10 which are predefined (ex: 1Water, 2-Buildings). We can add more objects if we want. The last column comprises the labeled area, which is multipolygon geometry represented in WKT format. The polygons can be more than one depending upon the objects available in the satellite images. This file consists of labeled data for 25 satellite images respectively.

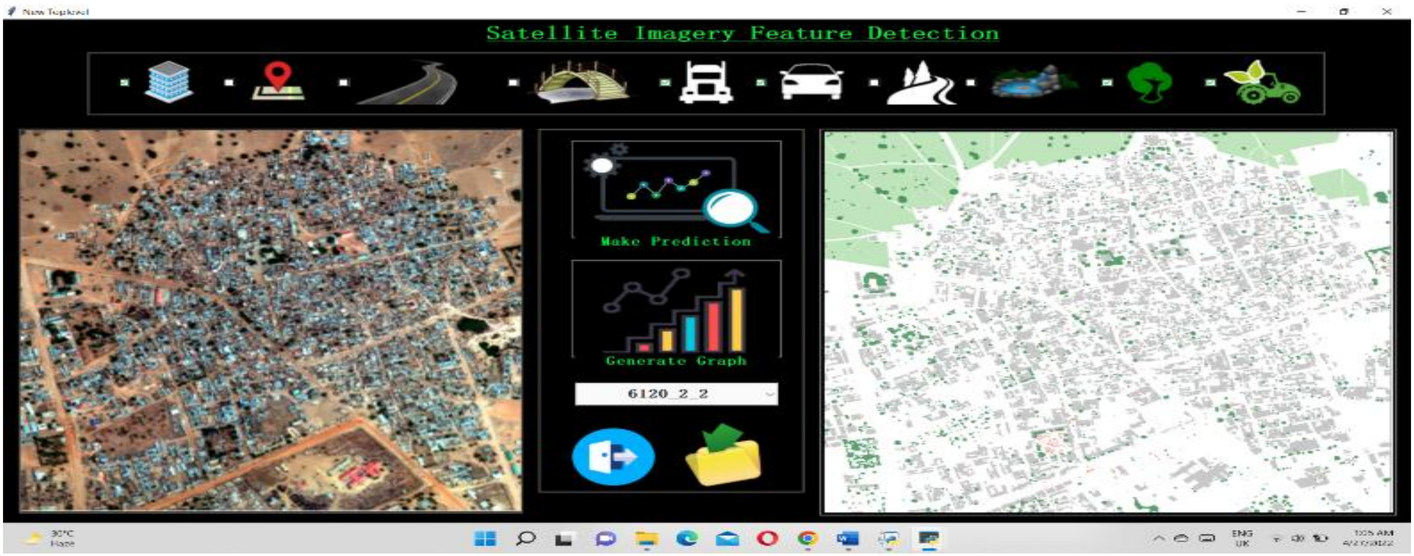
A1 fx ImageId

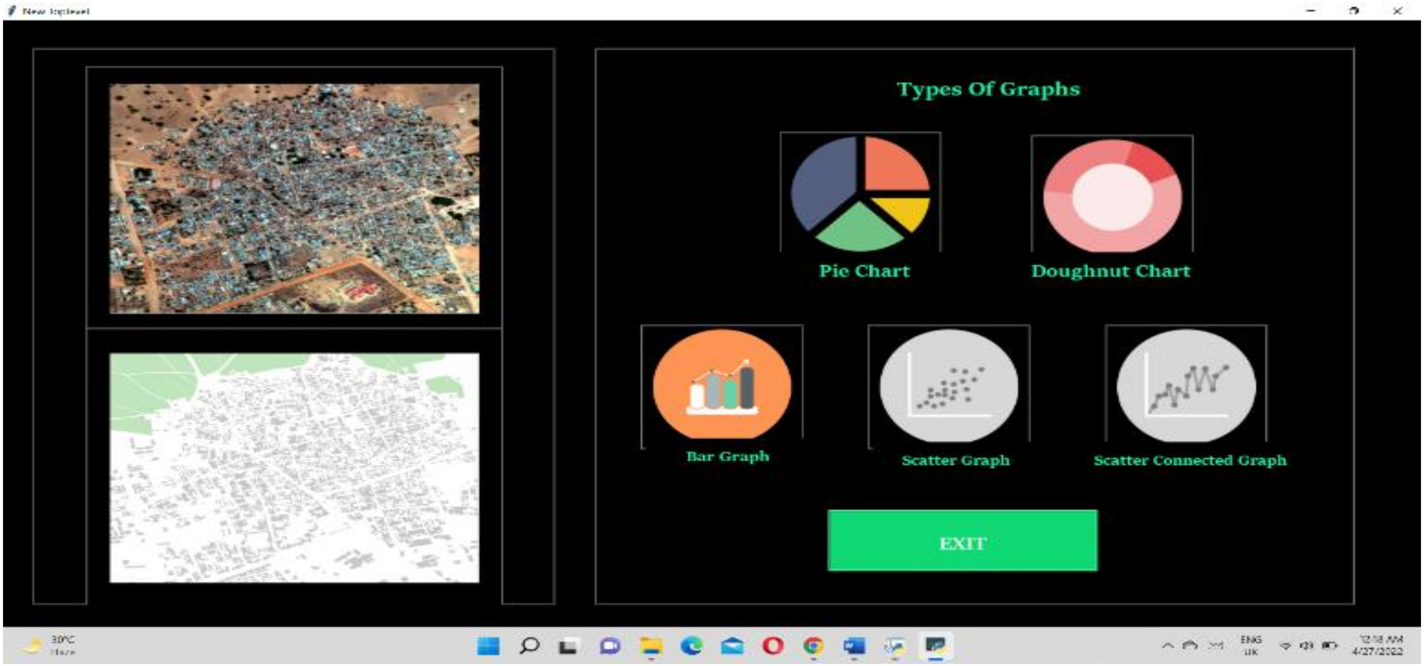
	A	B	C
1	ImageId	ClassType	MultipolygonWKT
2	I4_96_610	1	MULTIPOLYGON (((378879.147008843 1881951.9076691, 379841.594726338 18817
3	I4_96_610	2	MULTIPOLYGON (((387468.93839424 1883727.95337079, 387715.687668259 18837
4	I4_96_610	3	MULTIPOLYGON (((73.9136258792054 17.0020469219176,73.9149787532303 17.00
5	I4_96_610	4	MULTIPOLYGON EMPTY
6	I4_96_610	5	MULTIPOLYGON EMPTY
7	I4_96_610	6	MULTIPOLYGON (((73.9568883947663 17.0220904476569,73.9565448584469 17.02
8	I4_96_610	7	MULTIPOLYGON (((73.8591902940709 17.0519359692608, 73.8594191958646 17.05
9	I4_96_610	8	MULTIPOLYGON EMPTY
10	I4_96_610	9	MULTIPOLYGON EMPTY
11	I4_96_610	10	MULTIPOLYGON EMPTY
12	I4_96_611	1	MULTIPOLYGON (((404036.252440249 1879563.18062858, 404374.178527725 1879
13	I4_96_611	2	MULTIPOLYGON (((395823.469574466 1875136.93677714, 396307.033674932 1875
14	I4_96_611	3	MULTIPOLYGON (((74.1120186762055 16.97638279283,74.1153601651795 16.9750
15	I4_96_611	4	MULTIPOLYGON (((74.1448749195128 16.9616116865792,74.1393534252255 16.96
16	I4_96_611	5	MULTIPOLYGON (((74.1133220348875 16.9565458119613,74.1139483574756 16.95
17	I4_96_611	6	MULTIPOLYGON (((74.0829737168295 16.9770295509813,74.0854116134668 16.97
18	I4_96_611	7	MULTIPOLYGON (((74.0789826450744 17.0176057105716, 74.0829695757004 17.01
19	I4_96_611	8	MULTIPOLYGON (((74.1149521767342 16.9657108489311,74.1158938870916 16.96
20	I4_96_611	9	MULTIPOLYGON EMPTY
21	I4_96_611	10	MULTIPOLYGON EMPTY

Fig - CSV file of labeled data

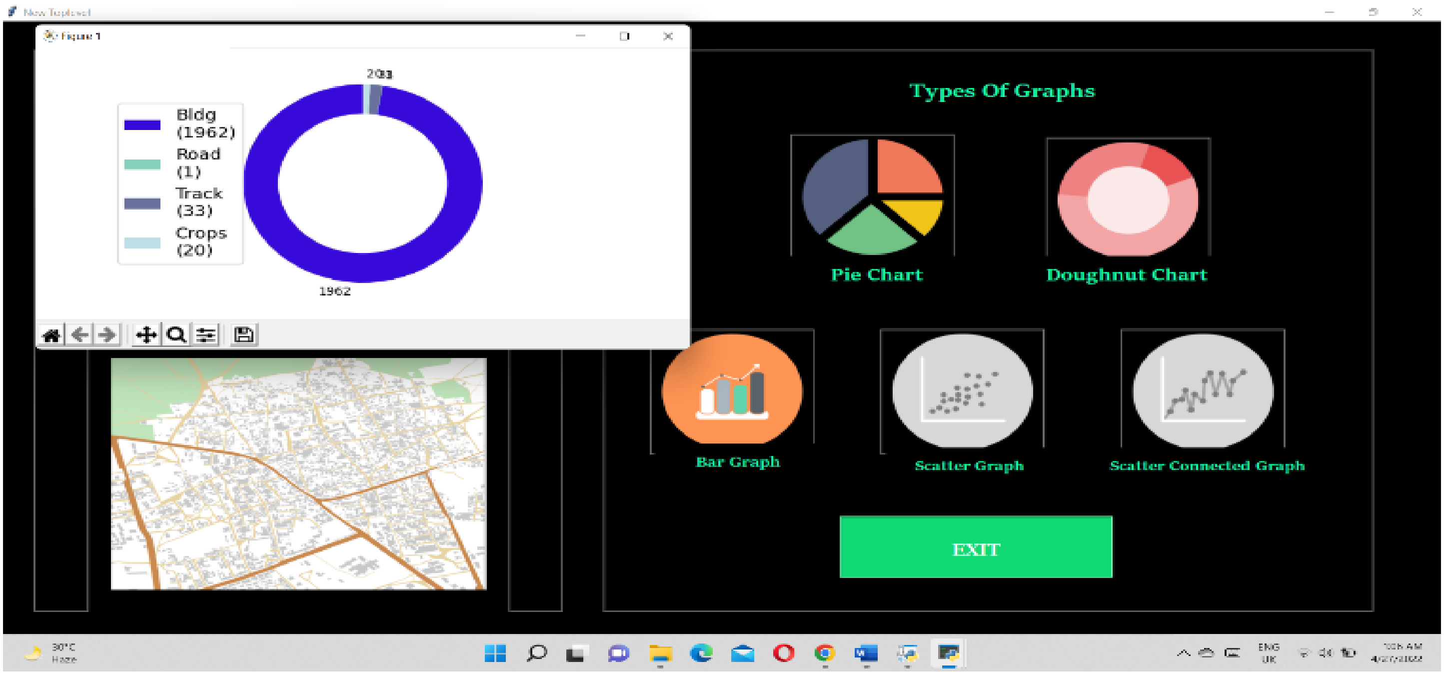
V. Experimental Result

In this part, we will look at a Keras-based implementation of a deep U-Net for satellite image segmentation. The dataset is made up of 8-and commercial-grade satellite imagery from the Space Net dataset. These files contain data on five distinct types of objects: Buildings, struct, trucks, roads, cars, plants, crops, Tracks, Slow H2O, and Fast H2O.

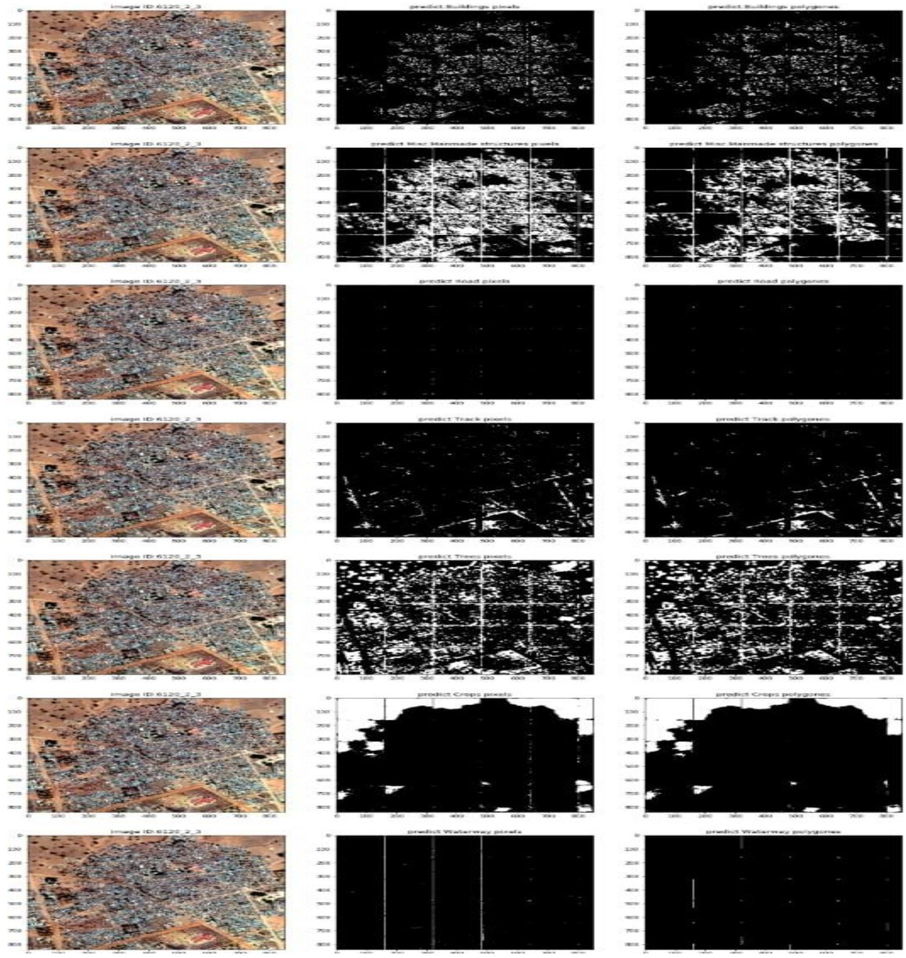




As shown in the above figure it gives us various types of graphical representation which describe the result from the object image.



Visualizing results on random validation results



Accuracy of this project:

```
start train net
(709, 8, 160, 160) (709, 10, 160, 160) 1.0 -1.0 1.0 0.0
Train on 709 samples, validate on 715 samples
Epoch 1/10
709/709 [==============================] - 22s 31ms/step - loss: 0.5655 - jaccard_coef: 0.0590 - jaccard_coef_int: 0.0577 - acc
uracy: 0.6995 - val_loss: 0.4017 - val_jaccard_coef: 0.0598 - val_jaccard_coef_int: 0.0618 - val_accuracy: 0.8588
Epoch 2/10
709/709 [==============================] - 15s 20ms/step - loss: 0.3128 - jaccard_coef: 0.0554 - jaccard_coef_int: 0.0479 - acc
uracy: 0.8963 - val_loss: 0.2744 - val_jaccard_coef: 0.0664 - val_jaccard_coef_int: 0.0637 - val_accuracy: 0.9276
Epoch 3/10
709/709 [==============================] - 14s 20ms/step - loss: 0.2383 - jaccard_coef: 0.0632 - jaccard_coef_int: 0.0603 - acc
uracy: 0.9312 - val_loss: 0.2158 - val_jaccard_coef: 0.0753 - val_jaccard_coef_int: 0.0652 - val_accuracy: 0.9378
Epoch 4/10
709/709 [==============================] - 15s 20ms/step - loss: 0.1993 - jaccard_coef: 0.0668 - jaccard_coef_int: 0.0609 - acc
uracy: 0.9383 - val_loss: 0.2026 - val_jaccard_coef: 0.0758 - val_jaccard_coef_int: 0.0660 - val_accuracy: 0.9438
Epoch 5/10
709/709 [==============================] - 14s 20ms/step - loss: 0.1770 - jaccard_coef: 0.0728 - jaccard_coef_int: 0.0622 - acc
uracy: 0.9446 - val_loss: 0.1743 - val_jaccard_coef: 0.0838 - val_jaccard_coef_int: 0.0695 - val_accuracy: 0.9488
Epoch 6/10
709/709 [==============================] - 14s 20ms/step - loss: 0.1627 - jaccard_coef: 0.0801 - jaccard_coef_int: 0.0689 - acc
uracy: 0.9494 - val_loss: 0.1703 - val_jaccard_coef: 0.0923 - val_jaccard_coef_int: 0.0760 - val_accuracy: 0.9531
Epoch 7/10
709/709 [==============================] - 15s 21ms/step - loss: 0.1524 - jaccard_coef: 0.0890 - jaccard_coef_int: 0.0752 - acc
uracy: 0.9521 - val_loss: 0.1719 - val_jaccard_coef: 0.0896 - val_jaccard_coef_int: 0.0771 - val_accuracy: 0.9524
Epoch 8/10
709/709 [==============================] - 14s 20ms/step - loss: 0.1489 - jaccard_coef: 0.0923 - jaccard_coef_int: 0.0746 - acc
uracy: 0.9524 - val_loss: 0.1717 - val_jaccard_coef: 0.0927 - val_jaccard_coef_int: 0.0931 - val_accuracy: 0.9513
Epoch 9/10
709/709 [==============================] - 15s 20ms/step - loss: 0.1419 - jaccard_coef: 0.0967 - jaccard_coef_int: 0.0809 - acc
uracy: 0.9543 - val_loss: 0.1466 - val_jaccard_coef: 0.1061 - val_jaccard_coef_int: 0.0987 - val_accuracy: 0.9565
Epoch 10/10
709/709 [==============================] - 14s 20ms/step - loss: 0.1378 - jaccard_coef: 0.0994 - jaccard_coef_int: 0.0824 - acc
uracy: 0.9555 - val_loss: 0.1528 - val_jaccard_coef: 0.1052 - val_jaccard_coef_int: 0.1060 - val_accuracy: 0.9565
(715, 10, 160, 160) (715, 10, 160, 160)
val jk0.7527248824239636
```

We obtained accuracy between 90 to 95 Percentage.

Incorporated Libraries And Packages

A. Pandas is a Python library used for working with data sets. It has functions for analyzing, cleaning, exploring, and manipulating data. Pandas allow us to analyze big data and make conclusions based on statistical theories. Pandas can clean messy data sets, and make them readable and relevant.

B. Matplotlib is a low-level graph plotting library in python that serves as a visualization utility. Matplotlib is open source and we can use it freely.

C. Pillow, the Python Imaging Library adds image processing capabilities to your Python interpreter. This library provides extensive file format support, an efficient internal representation, and fairly powerful image processing capabilities.

D. EfficientNet PyTorch is a PyTorch re-implementation of EfficientNet.It is consistent with the original TensorFlow implementation, such that it is easy to load weights from a TensorFlow checkpoint. At the same time, we aim to make our PyTorch implementation as simple, flexible, and extensible as possible.

VI. Conclusion

The machine learning-based feature extraction and object detection using high-resolution satellite images is being designed for RRSC-C, ISRO, and Nagpur. The system consists of a classifier that helps in extracting the information contained in different bands of the satellite sensor. This information is extracted in terms of digital numbers which are then converted to a category. This system is implemented to detect objects like landmass, waterbody, and forests. The data is in the form of an image that is captured by a satellite. The image captured by satellite is converted into tiff format while processing is done. There will be different cameras on the satellite which will be used for image capturing. The captured image will be processed in different bands needed for identification purposes. This image is fed to the system which contains an NVIDIA GPU processor installed in the server room. NVIDIA in the system shows the image predicted by the user against the image. The neural network model is used for the segmentation to get the predicted pixels for each class. The output screen displays a black image with white pixel-sized polygons which refers to the class in the program. Hence, the output of the program is obtained. The currently developed system can further be trained to give more efficient results for different band images. The second thing which can be done is to make the website in which direction the image will be imported and the rest of the process is executed automatically. Furthermore, the data being used to classify can be made more accurate so accuracy will increase further.

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