DETECTION AND OF LANDSLIDE VULNERABILITY THROUGH LAND DEFORMATION STUDY USING DINSAR AND DEEP LEARNING TECHNIQUES

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CERTIFICATE

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DECLARATION

We hereby declare that the MINI project entitled **"DETECTION AND PREDICTION OF LANDSLIDE VULNERABILITY THROUGH LAND DEFORMATION STUDY USING DINSAR AND DEEP LEARNING TECHNIQUES"** submitted for the B.Tech Degree is our original work and the dissertation has not formed the basis for the award of any degree, associate-ship, fellowship or any other similar titles.

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Abstract

Landslides are among the most deadly natural catastrophes because they usually occur after other severe disasters, causing enormous damage to already vulnerable systems. India had almost 10,900 deaths from 829 landslides, or 18 percent of all global casualties and accounted for 28 percent of landslide incidents brought on by building. Remote sensing approaches for landslide monitoring and prediction have grown in prominence in recent years due to their ability to mitigate hazards. Interferometry using Synthetic Aperture Radar (SAR) is one of the remote sensing methods employed. In this proposed system we use DInSAR technique for the phase difference calculation over a specific area using the sensors of the Sentinel-2 satellite. SR-530(Oso landslide, WA, USA) is our field of study for assessing the properties and parameters required in order to detect and predict the landslides. Sentinel-2 is a multispectral imaging satellite, from which we generated DEM(Digital Elevation Model) from Differential SAR Interferometry technique(DInSAR) through interferometric patterns generated through Interferograms. Along with DEM we obtained Slope of the area from ArcGIS tool. Normalized Difference Vegetation Index(NDVI) is also taken to detect and quantify the presence of land erosion and general RGB image are considered. This can be used to predict the activity of landslides from the Unet Model training through various data samples obtained from different areas using the land deformation study properties from SR-530 and validating the results. From the collected data, further subsidence maps and graphs were also produced, in general these findings calibrate and assess the forthcoming landslides.

Keywords: Landslide detection, DInSAR technique, Unet Model, NDVI, Remote Sensing, Interferometry, ArcGIS, SNAP Tool.

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1 INTRODUCTION

Landslide is movement process, translational or rotational mass move over a stable subsoil. Movements are occurring along clear, or unclear slip surface. Mass moving down the slope can be slow and barely noticeable in time, but it also can be very quickly and devastating. Landslides can be detected by analysing the environmental data collected by wireless sensor networks. However, environmental data is complex and undergo rapid changes.

In the Landslides occurred in northwest Washington on March 22, 2014, leading to tragic loss of life and destruction of property. Landslide debris covered about 40 homes and other structures as well as nearly a mile of State Route 530. It also caused 43 fatalities in the community of Steelhead Haven near Oso, Washington., The area overrun by the landslide was about one-half square mile, and the landslide moved about 18 million tons of sand, till, and clay. That amount of material would cover approximately 600 football fields 10 feet deep. The slide dammed the North Fork Stillaguamish River to a depth of as much as 25 feet, forming a temporary lake 2.5 miles long, which flooded houses and other structures in Steelhead Haven.

In the 6-8 weeks following the landslide, the river slowly eroded back to near its pre-landslide elevation, effectively draining the remaining excess water by the middle of May. The landslide involved a complex sequence of events—including rotation, translation, and flow mechanisms—and can be referred to as a debris-avalanche flow. Studies indicate that slope failure occurred in two stages over the course of about 1 minute. The main objective of this project is to impart equipped techniques in

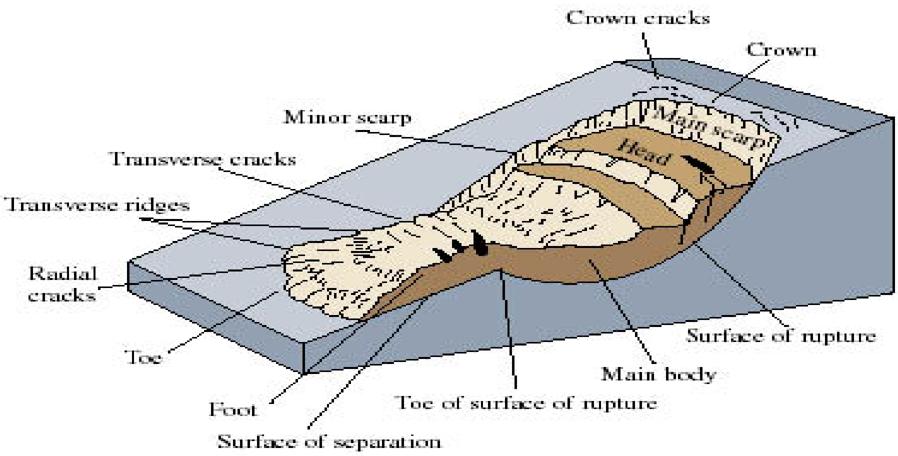


Figure 1: Landslide

early detection of the landslide occurrence and prevent the human loss. This involves predicting whether a region is susceptible to landslide or not. To find out the probability of occurrence of the landslide. Figure 1 represents An idealized slump-earth flow showing commonly used nomenclature for labeling the parts of a landslide. [1]

1.1 Basic Concepts

DInSAR

DInSAR uses radar images to measure centimeter-level surface displacements. In the images, ground resolution can be relatively high, with each data point (pixel) representing the average displacement over an area of several square meters. DInSAR techniques exploit the information contained in the phase of the radar microwave of 2.8 cm half-wavelength, of at least two complex SAR images acquired in different epochs over the same area, forming an interferometric pair. Differential Interferometric Synthetic Aperture Radar (DInSAR), a satellite-based remote sensing technique, has application for monitoring subsidence with high resolution over short periods. PInSAR is used to overcome the disadvantages in it.Figure 2 represents the working of DInSAR. [2]

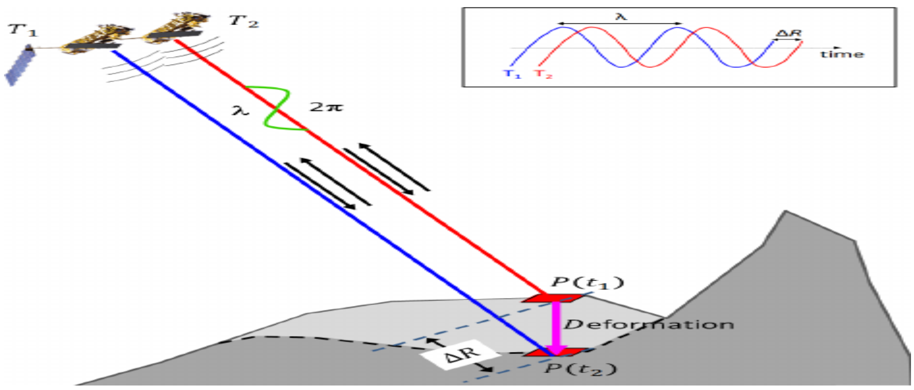


Figure 2: DInSAR

Deep Learning

Deep Learning is a part of Machine Learning used to solve complex problems and build intelligent solutions. The core concept of Deep Learning has been derived from the structure and function of the human brain. Deep Learning uses artificial neural networks to analyze data and make predictions. Deep learning, when applied to data science, can offer better and more effective processing models. But the drawback is It requires very large amount of data in order to perform better than other techniques. Each level uses the representation produced by previous level as input, and produces new representations as output, which is then fed to higher levels.Figure 3 represents the block diagram of CNN. [3]

SAR(Synthetic Aperture Radar)

Synthetic-aperture radar (SAR) is a form of radar that is used to create two-dimensional images or three-dimensional reconstructions of objects, such as landscapes. SAR uses the motion of the radar antenna over a target region to provide finer spatial resolution than conventional stationary beam-scanning radars. To create a SAR image, successive pulses of radio waves are transmitted to "illuminate" a target scene, and the echo of each pulse is received and recorded. The pulses are transmitted and the echoes received using a single beam-forming antenna, with wavelengths of a meter down to several millimetres. Figure 4 represents the process of machine learning. [4]

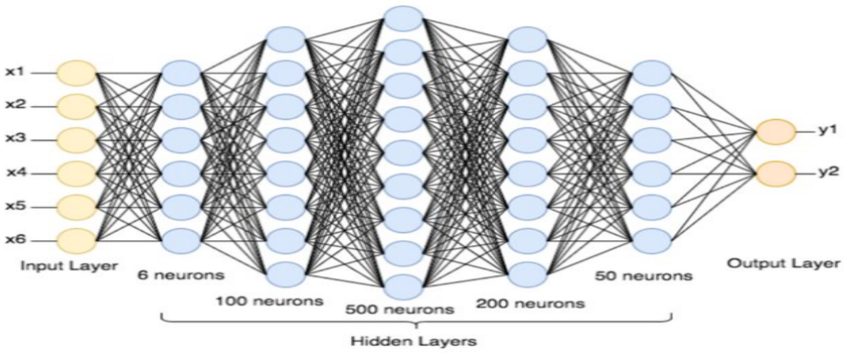


Figure 3: Deep Neural Network architecture

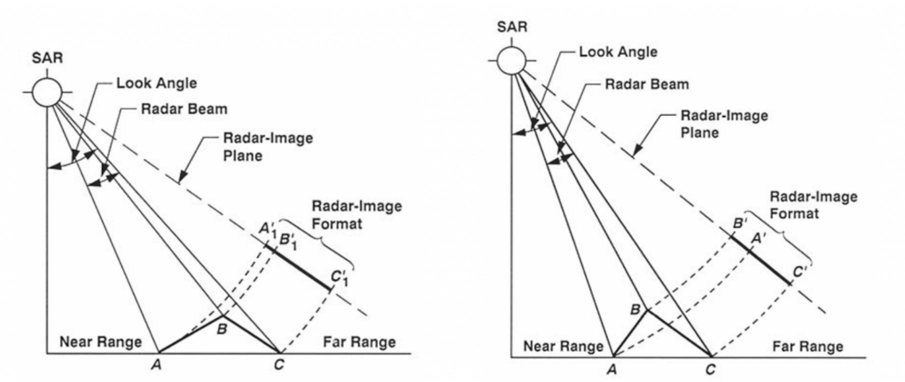


Figure 4: SAR Image Interpretation

1.2 Motivation

- The main motive of this project is to prevent the human and environmental damage causing due to the sudden, un-informed attack by landslide.
- Many people living in the hilly regions and other regions susceptible to landslides are becoming the victims of the landslide.
- By early detection of landslide using the remote sensing method can solve this problem.
- The government of will be informed after predicting that the region is susceptible to landslide, so that, necessary emergency actions

Figure 5 represents the human and environment loss faced due to landslides. [5]

1.3 Problem Statement

Landslides are a type of disasters which occur frequently in many mountain regions and regions having slopes. Landslides may be caused due to rainstorms, earthquakes, weathering processes and other indigenous activities like cutting the road. These cause severe damage to environment as well as to the human life. The existing methods

Figure 5: Adverse effects of landslides

include evacuating the people nearby only when the landslide started occurring. If we try to predict the fore coming landslides in prior, the damage could be reduced and lot many lives can be saved. The aim of the project is to determine the fore coming landslides using the DInSAR technique and deep learning methodologies.This uses the data collected by the Landsat satellite.

1.4 Scope

- The scope of the project focuses on areas with landslide risk, so that a safe and efficient early warning can be emitted for potential risk situations.
- This involves prediction using the data collected by the sentinel-2 satellite through DEM

1.5 Objective

- The main objective of this project is to impart equipped techniques in early detection of the landslide occurrence and prevent the human loss.
- This involves predicting whether a region is susceptible to landslide or not.
- To find out the probability of occurrence of the landslide.

1.6 Advantages

- It helps to prevent the human loss
- It helps in continuous monitoring of the susceptible regions
- It also helps in taking preventive measures for avoiding it, if possible
- It helps in prevailing social, economic and environmental damage caused due to landslides

- It helps in preventing the blockage of river due to landslides.
- It helps in preventing the infrastructure, forest and agricultural resources loss.

1.7 Applications

- It can be used by government and the rescue teams to get prepared for the fore-coming landslide.
- It can be used by the rescue teams to evacuate the people in prior to reduce human loss.
- It can be used by tourist organizations and travel agencies to plan accordingly.
- It can be used to analyse the intensiveness of the landslide and record them
- It can also be used by NGO's to prevent the pollution of rivers due to landslides.

2 LITERATURE SURVEY

This section contains the list of research papers that we have studied under literature survey. We focused on the approaches for maintaining accuracy in these papers. Our study included the techniques used for developing and training the model.

2.1 Landslide detection using deep learning and object-based image analysis

Omid Ghorbanzadeh et al [6] proposed pixel-based deep learning approach to detect the landslides fron the sentinel-2 imagery. It utilizes ResU-net, Object based image analysis and ResU-net-Object based image analysis. The value of each pixel in the heat map refers to the probability that the pixel belongs to either landslide or non-landslide classes. The results from these three scenarios will be compared and analysed to predict the susceptibility of landslide. The area under study for this project Is Taiwan region after Morakot typhoon in august 2013.

Advantages

- It uses the combined approach of ResU-Net and OBIA for accurate results.
- The integrated approach gave 73.14 percent accuracy compared to the ResU-Net alone, which gave accuracy of 61.29 percent

Disadvantages

- The improvement in recall value in combined approach is not as significant as that of precision: only a three percentage-point increase is obtained.
- It is confined only to data collected through remote sensing methods.

2.2 Geoinformatic Analysis of Rainfall-Triggered Landslides in Crete (Greece) Based on Spatial Detection and Hazard Mapping

Athanasios V. Argyriou et al [7] proposed a project which mainly deals with detection of landslides caused due to heavy rainfall in Mediterranean Crete region , determine the interaction between the triggering factor of rainfall and other conditioning factors and estimate the spatial component of a hazard map by spatially indicating the possibility for rainfall-triggered landslides when similar rainstorms take place in the future.

Advantages

- Visual interpretation of the temporal satellite images is used to overcome the topography-based shadow effects.
- The domino-effect is also considered while predicting the climatic changes

Disadvantages

- The conditioning factors and the threshold values used in it can slightly have a mismatch with the location of landslide.
- It is confined only to data collected through remote sensing methods.

2.3 Landslide Detection Using Densely Connected Convolutional Networks and Environmental Conditions.

Haojie Cai et al [8] proposed a project which utilizes the advantages of dense convolutional networks (DenseNets) and their modified technique to solve the detection of landslides. According to the environment of the study area, aspect, slope, elevation, terrain relief, profile curvature, plan curvature, lithology, bedding structure, NDVI, MNDWI, distance to fault, and rivers are added to construct new landslide samples.

Advantages

- DenseNet can improve the accuracy of the detection model. Compared with the optical image, kappa and F1 increased by 9.7 percent and 9.1 percent respectively.
- Compared with other traditional neural networks and machine learning algorithms, DenseNet has the highest kappa and F1 values.

Disadvantages

- It is confined only to data collected through remote sensing methods
- It is unable to detect micro landslides

2.4 Small Scale Landslide Detection Using Sentinel-1 InSAR Coherence,

Marios Tzouvaras et al [9] proposed a system to detect landslides in Cyprus region. This paper aims to demonstrate how the use of Copernicus open-access and freely distributed datasets along with the exploitation of the open-source processing software SNAP (Sentinel's Application Platform), provided by the European Space Agency, can be used for landslide detection where landslide is caused due to rainfall. All coherence maps produced in SNAP were inserted in ArcGIS, where the sea was subtracted, and coherence values were classified appropriately for the development of the final coherence products.

Advantages

- Cohérent Change Détection (CCD) technique for landslide detection along with DInSAR technique
- The true-positive rate, which is also known as sensitivity or probability of landslide detection, was 63.2 percent in the case of the coherence difference and increased to 73.7percent for the normalized coherence difference.

Disadvantages

- probability of false detection of landslide was approximately 1 perent.
- It is confined only to data collected through remote sensing methods.

2.5 Review of Satellite Interferometry for Landslide Detection in Italy

Lorenzo Solari et al [10] proposed the work reviews a variety of InSAR-related applications for landslide studies in Italy. More than 250 papers were analysed in this review. The first application dates back to 1999. The average production of InSAR-related papers for landslide studies is around 12 per year, with a peak of 37 papers in 2015.This review just provides the complete analysis of landslide detection. This paper is aimed to illustrate the role of satellite interferometry for landslide monitoring and mapping in Italy.

Advantages

- Approximately 253 papers were reviewed for analysing
- It revealed that there are two main areas where InSAR is used as input for models: single landslide modelling or basin-scale susceptibility modelling

Disadvantages

- This review is neither focused on technical aspects, nor on a general presentation of the InSAR advantages and limitations.

2.6 Landslide Detection Using Remote Sensing A Review of Current Techniques.

Byrraju, S. V et al [11] proposed a system to detect landslides in 3 chosen areas(Etna, California Highway 1, Anargyroi Greece) which have unique factors that cause the landslide. The data for this analysis is obtained using Sentinel-1 satellite which is a C-band SAR sensor. The 3 locations have been analysed for a period of 36 days with sensor taking acquisitions every 12 days. Coregistration is the critical step in which pixel to pixel matching is performed on two acquisitions so that accurate phase difference can be calculated in order to increase coherence and reduce the noise.

Advantages

- DInSAR analysis is performed using SRTM DEM as reference to develop phase maps of the area
- Test the extent of DInSAR in analyzing landslides and to test if these techniques can be used in landslide recognition.

Disadvantages

- It is affected by layover and shadowing principles
- It is confined to limited region only.
- It uses remote sensing methods only.

2.7 Evaluation of Different Machine Learning Methods and Deep-Learning Convolutional Neural Networks for Landslide Detection.

Ghorbanzadeh et al [12] proposed a system which uses optical data from the Rapid Eye satellite and topographic factors to analyse the potential of machine learning methods, and different deep-learning convolution neural networks for landslide detection. The case study area lies in the southern part of the Rasuwa district in Nepal along a highway that connects Nepal to China. The spectral information from Rapid Eye images was used in combination with some conditioning topographic factors to evaluate the performance.

Advantages

- It shows the impact of input window size and layer depth in detecting the landslides.
- The mIOU(Mean Intersection-over-Union) metric used to measure the accuracy of the result.

Disadvantages

- Topographical information slightly reduced the overall accuracy of the results
- It was unable to conclude whether the topographic information has affect on the detection or not
- It uses remote sensing methods only.

2.8 Landslide detection in mountainous forest areas using polarimetry and interferometric coherence

Ohki et al [13] proposed a system to detect the landslides in mountain regions which is difficult because of significant decorrelation. This combines polarimetric SAR (PolSAR), InSAR, and digital elevation model (DEM) analysis to detect landslides induced by the July 2017 Heavy Rain in Northern Kyushu and by the 2018 Hokkaido Eastern Iburi Earthquake. This study uses fully polarimetric L-band SAR data from the ALOS-2 PALSAR-2 satellite.

Advantages

- It also takes into account the LIA(Local Incidence angle) too in dealing with surface scattering.
- Obtained higher accuracy by combining many parameters from PolSAR, InSAR, and DEM.

Disadvantages

- Due to the long temporal distance, mistakenly detects a deforested area as a landslide .
- The results are affected by layover affect.
- It uses remote sensing methods only.

3 ANALYSIS AND DESIGN

This section includes the analysis of requirements for the proposed project. This chapter contains functional and non functional requirements.

3.1 Functional-Requirements

Functional requirement analysis entails a thorough examination, analysis, and description of software requirements and hardware requirements in order to meet actual and also necessary criteria in order to solve an issue. Analyzing functional Requirements includes a number of processes. The Functional Requirements include:

Software Requirements

Open-CV:
OpenCV-Python is a library of Python bindings designed to solve computer vision problems. Python is a general purpose programming language started by Guido van Rossum that became very popular very quickly, mainly because of its simplicity and code readability.OpenCV is an open-source library for the computer vision. It provides the facility to the machine to recognize the faces or objects.All the OpenCV classes and functions are placed into the cv namespace. a compact module defining basic data structures, including the dense multi-dimensional array Mat and basic functions used by all other modules.[14]

Unet:
U-Net is a convolutional neural network that was developed for biomedical image segmentation. The network is based on a fully convolutional network whose architecture was modified and extended to work with fewer training images and yield more precise segmentation.U-net architecture is symmetric and consists of two major parts. The left part is called the contracting path, constituted by the general convolutional process.The right part is an expansive path, constituted by transposed 2D convolutional layers.In CNN, the image is converted into a vector which is largely used in classification problems. But in U-Net, an image is converted into a vector and then the same mapping is used to convert it again to an image. This reduces the distortion by preserving the original structure of the image.[15]

Snap Tool:
The Sentinel Application Platform (SNAP) is a common architecture for all Sentinel Toolboxes. The software is developed by Brockmann Consult, Skywatch, Sensar and C-S.The SNAP architecture is ideal for Earth observation (EO) processing and analysis due to the following technological innovations: extensibility, portability, modular rich client platform, generic EO data abstraction, tiled memory management, and a graph processing framework.SNAP and the individual Sentinel Toolboxes support numerous sensors other than Sentinel sensors.ESA/ESRIN is providing the SNAP user

tool free of charge to the Earth Observation Community.[16]

Acrgis Pro Tool:
ArcGIS Pro, the powerful single desktop GIS application, is a feature-packed software developed with enhancements and ideas from the ArcGIS Pro user community. ArcGIS Pro supports data visualization; advanced analysis; and authoritative data maintenance in 2D, 3D, and 4D. It supports data sharing across a suite of ArcGIS products such as ArcGIS Online and ArcGIS Enterprise, and enables users to work across the ArcGIS system through Web GIS. Discover the full spectrum of tools and capabilities within ArcGIS Pro today.[17]

Hardware Requirements

- Recommended Intel Core i5 8400 or AMD Ryzen 5 3000 Series
- Recommended Windows 10 64-bit, Windows 11 64-bit
- Minimum of 8GB Ram
- 20 GB of available hard disk drive space
- Recommended: 2.6 GHz, 4 cores
- NVIDIA/AMD GPU for faster runtimes of Unet
- Window, linux or Mac Operating system

3.2 Non-Functional Requirements

Non functional requirements are the constraints imposed on the functional requirements.

- The area of interest should be of considerable area
- The Digital Elevation Model should be of atleast 12.5m resolution
- NDVI has to be constructed from band 5 and band 4.
- The cloud cover should be less than 10 percent
- The Digital Elevation Model should be only from SAR satellites

3.3 Design Diagram

Design diagram is a diagram which is a visual representations of various parts to the whole project.Figure 6 represents different activities in the project.

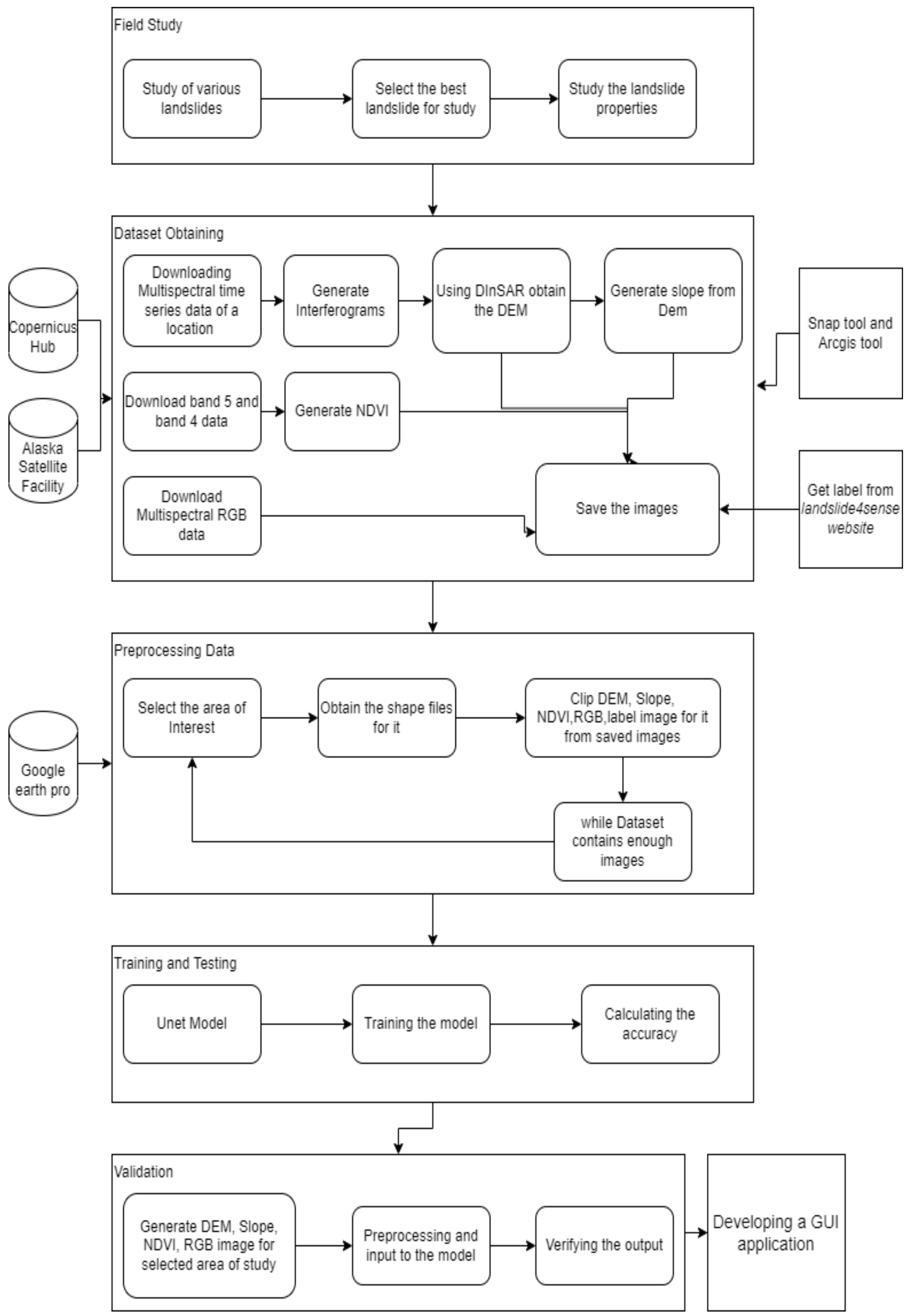


Figure 6: Design diagram

The first block denotes the module 1 which is the field study. In field study, we study the various types of landslides and various properties of landslides. Then we selected a best landslide for study which covers the properties of majority of the landslides. This landslide is studied further to analyze its properties.

The second block is about the module 2 which indicates the process dataset obtaining. Here the data required is gathered for a large area until the whole globe is covered. The data consists of DEM, Slope, NDVI, RGB, Label. The DEM is generated in snap tool using the data gathered from the copernicus hub and alaskan satellite facility. Then DEM is then loaded into the ARCGIS tool and then Slope is generated. Then for NDVI, band 4 and band 5 are collected from the copernicus hub and loaded into the ARCGIS tool. Using raster calculator generate NDVI. For RGB image, It is directly downloaded from the copernicus hub. The label is obtained from the landslide4sense website. All these data is stored location wise.

All the collected data is loaded into the ARCGIS tool and clipped into small sizes rasters according to the model requirements. This is done with the help of the shapefiles. These shapefiles are generated using the google earth pro tool and ARCGIS tool. Using the "Clip Raster" tool, the small size raster is clipped from a large raster according to the shapefile. This is done till the dataset contains enough images.

The fourth block indicates trainig part. The model is created as per the Unet Architechture. The model is tarined on the dataset created. This model is tested on the test data.

The fifth module is about the validation of the model. The trained model is tested with the data generated for the field study data. The DEM, Slope, NDVI, RGB data is generated for the field study area and uploaded to python and given as input to the model and the results are observed.

The last module is about developing a GUI Application for this functionality. The GUI application is developed using the Tkinter framework. This application takes input the four parameters and gives input these images to the model and generated the output graph. This graph is converted into an image and stored in local space. This image is displayed on the application window.

4 SOFTWARE DESIGN

This chapter consists of the design of the software Life Cycle model diagrams and their detailed explanation. Design is about choosing the architecture and solutions appropriate to the problem.

4.1 Software Development Lifecycle: Scrum Model

The project is divided into 3 sprints. The sprint backlogs in Figure 7 are Field Study, Rastering DEM,NDVI,Slope,Label and Apply Unet. Priorities are assigned to each backlog and based on the priorities the backlogs are implemented. During the each backlog implementation, the daily scrum meeting are conducted that helps to know What work from last meet? What work done? Are there any roadblocks in your way? and after the backlog complete, retrospection is done. This process is repeat until all the backlogs are finished.
The Figure 7 describes the lifecycle model used for the proposed model.

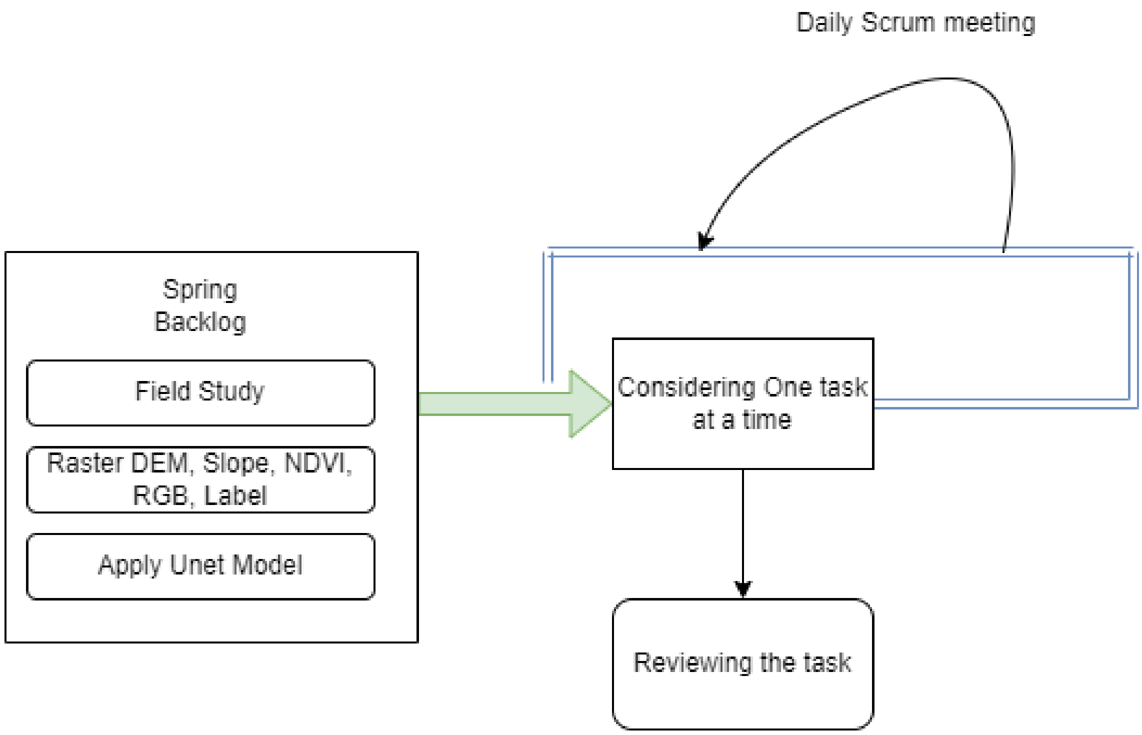


Figure 7: Scrum model

4.2 UML Diagrams

4.2.1 Use-Case Diagram

A use case diagram is a UML behaviour or dynamic diagram. Actors and use cases are used to model the functioning of a system (Figure 8) in use case diagrams. In this system, the programmer apply Unet Model to the dataset and store in a dataframe. The user upload image through GUI and prompt for landslide prediction label and graph results to the given image. The image will go to the Unet model and gives the top 10 image labels of high probability. These images are then mapped with the trained model to find the maximum inliers and label is given.Figure 8 represents the Use Case Diagram of the landslide detection project work.

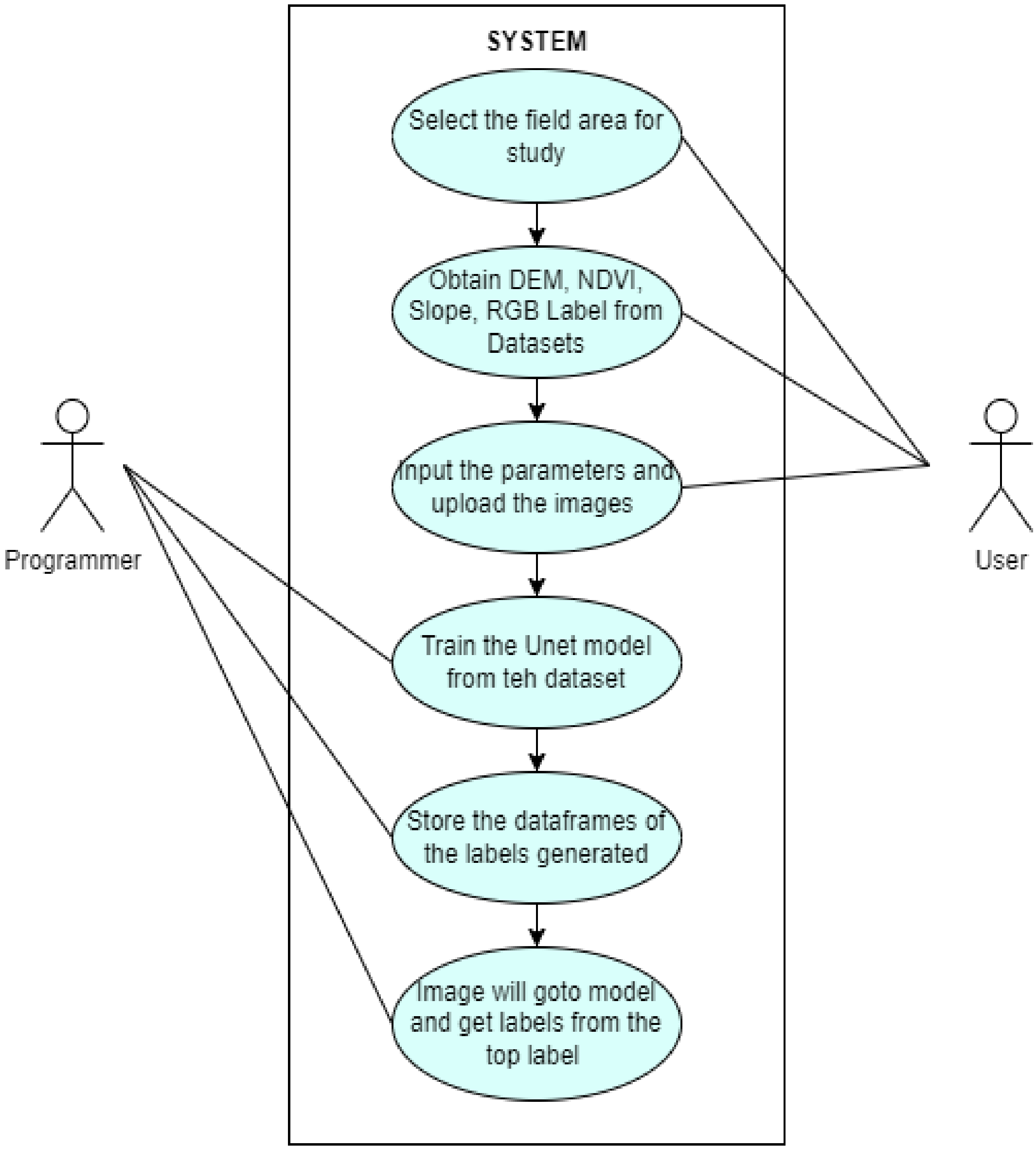


Figure 8: Use Case Diagram

4.2.2 Sequence Diagram

A sequence diagram simply shows how things interact in a sequential manner, or in the order in which these interactions occur. In figure 9, the actor or user initiates the interaction with the application. The user open or runs the application. Then the application opens and an "upload" button will be diaplayed on the window. The user clicks on the "upload" button on the window. The interface will then open a file select dialog box. The user will then select the required images. The interface will get the paths of images selected and sends them to the controller program. The controller program, loads the images and predicts the landslide susceptibility by giving them to the trained model and return the numpy array. This array is converted into an image and sent to the interface. The image is displayed on the window for user as a result. Finally the user closes the window.Figure 9 represents the sequence diagram of the project work.

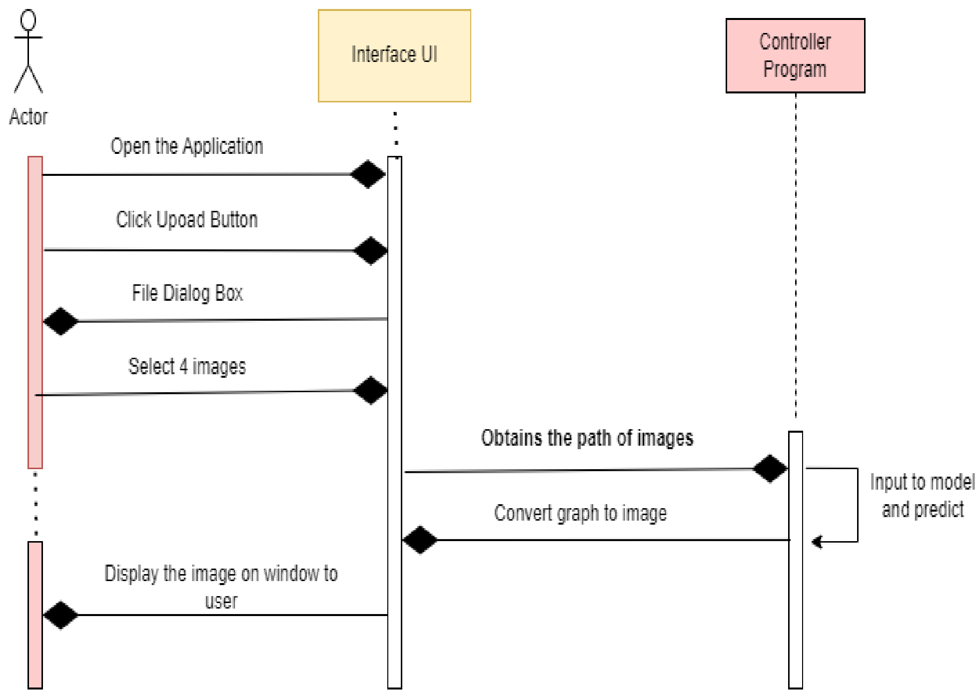


Figure 9: Sequence Diagram

5 PROPOSED SYSTEM

This section includes the process flow diagram and methodology along with the algorithms of modules.

5.1 Process Flow Diagram

A flow diagram displays graphically the project's methodology and seeks to more logically order the activities therein.

Figure 10 represents flow chart of the project. This flow chart describes the process

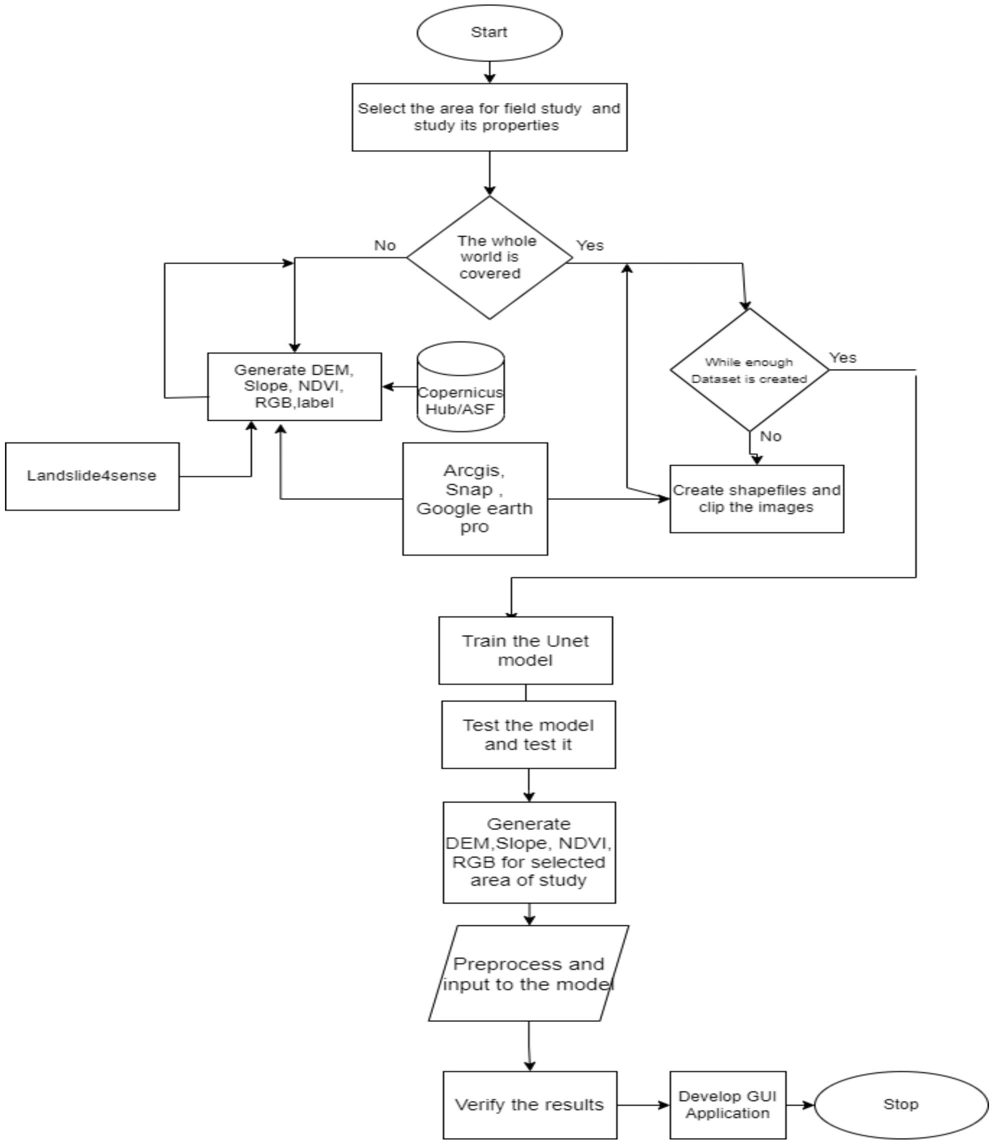


Figure 10: Process flow diagram

followed to achieve the desired results and also describes the methodology.

5.2 Methodology

The methodology of this project involves six modules in total. The main objective is to detect the landslide using land deformation techniques predict the fore-coming landslides. This involves finding the landslide susceptibility of the given region. It takes help of four different parameters like DEM, Slope, NDVI,and RGB image for finding out the landslide susceptibility of the required region.

Field Study

For obtaining the better results, the first step will be gaining enough information. For this we have to study various landslides across the globe. We have analyzed various landslide types and various landslide properties. There are different factors that cause the landslide. All these factors and properties are kept in view and the best landslide is selected which depicts the majority of the landslides. The SR-530 landslide best suits the need.

The Oso landslide, also known as the SR 530 landslide, occurred in northwest Washington state on March 22, 2014, leading to devastating loss of life and destruction of property. Landslide debris blocked the North Fork Stillaguamish River, destroyed about 40 homes and other structures, and buried nearly a mile of State Route 530. Most tragically, it caused 43 fatalities in the community of Steelhead Haven near Oso, Washington.Oso was emblematic of a worst-case landslide scenario. As such, U.S. Geological Survey scientists have identified it as a key geological-hydrological event that can help explain and inform our understanding of the potential effects of landslides in other settings in the United States and worldwide. USGS scientists have been studying this event since the landslide occurred[18].Figure 11 shows the after effect of oso landslide.

Figure 11: Oso Landslide

Dataset Obtaining

The next step will be developing a dataset for training a model on determining the landslide susceptibility. For this we have chosen few large areas where landslides occur frequently across the globe. These areas cover nearly thousands of kilometers. For these areas, we can download the sentinel-1 satellite data which is readily available in the copernicus open access hub. We choose sentinel-1 satellite because it is the latest SAR(Synthetic Aperture Radar) satellite which provides data with better precision and accuracy.From this data we can obtain DEM and slope.Using the Snap tool we can generate the DEM for the required location. This uses DinSAR technique. Interferometric synthetic aperture radar (InSAR) exploits the phase difference between two complex SAR images taken from slightly different sensor positions and extracts information about the earth's surface.This Interferogram along with the external DEM is processed and differenced to obtain the DInSAR DEM.For this we need 2 time series sentinel-1 satellite data of the same location.The DEM generation steps are as follows [19]

- **Install snaphu**:Two-dimensional phase unwrapping is the process of recovering unambiguous phase data from a 2-D array of phase values known only modulo 2pi rad. SNAPHU is an implementation of the Statistical-cost, Network-flow Algorithm for Phase Unwrapping proposed by Chen and Zebker[20]
- **Open**: Open the two products in the snap tool
- **TOPS Split**:S-1 TOPS Split is applied to the data to select only those bursts which are required for the analysis.
- **Apply orbit file**:This is a SNAP inline step for acquiring the satellite orbit file. Usually the satellite flying orbit track is being detected by many sensors, like mounted gyro, GPS, and also ground observations. To calculate out the precise orbit data takes time, so the precise orbit data are not included in many SAR satellite data bundles. SNAP is trying to get more precise orbit data to help to improve the geocoding and other SAR processing results
- **Back Geocoding and Enhanced Spectral Diversity**: The S-1 Back Geocoding operator coregisters the two split products based on the orbit information added in the previous step and information from a digital elevation model (DEM) which is downloaded by SNAP.
- **Interferogram Formation and Coherence Estimation**:An interferogram is formed by cross multiplying the reference image with the complex conjugate of the secondary. The amplitude of both images is multiplied while the phase represents the phase difference between the two images.
- **TOPS Deburst**:To remove the seamlines between the single bursts, the S-1 TOPS Deburst operator is applied to the interferogram product.
- **Goldstein Phase Filtering**:Interferometric phase can be corrupted by noise from temporal and geometric decorrelation, volume scattering, and other processing errors. Phase information in decorrelated areas cannot be restored, but

the quality of the fringes existing in the interferogram can be increased by applying specialized phase filters, such as the Goldstein filter which uses a Fast Fourier Transformation (FFT) to enhance the signal-to-noise ratio of the image.

- **Phase Unwrapping**:Phase unwrapping is the most complicated stage of interferometric data processing.The interferometric phase is ambiguous and only known within 2π. In order to be able to relate the interferometric phase to the topographic height, the phase must first be unwrapped. The altitude of ambiguity is defined as the altitude difference that generates an interferometric phase change of 2πi after interferogram flattening.Phase unwrapping solves this ambiguity by integrating phase difference between neighboring pixels. After deleting any integer number of altitudes of ambiguity (equivalent to an integer number of 2π phase cycles), the phase variation between two points on the flattened interferogram provides a measurement of the actual altitude variation. Figure 12 represents Principle of phase unwrapping. It involves export, unwrap, import steps.

- **Phase to Elevation**:The unwrapped phase is now a continuous raster but not yet a metric measure. To convert the radian units into absolute heights, the Phase to Elevation operator (under Radar $\geq$ Interferometric $\geq$ Products) is applied. It translates the phase into surface heights along the line-of-sight (LOS) in meters. The LOS is the line between the sensor and a pixel. A DEM is used to put the elevation values in the correct level.

- **Range Doppler Terrain Correction**:Terrain Correction will geocode the image by correcting SAR geometric distortions using a digital elevation model (DEM) and producing a map projected product. This results in the generation of DEM.

- **Export**:After the DEM has been generated export it in the .geotiff format

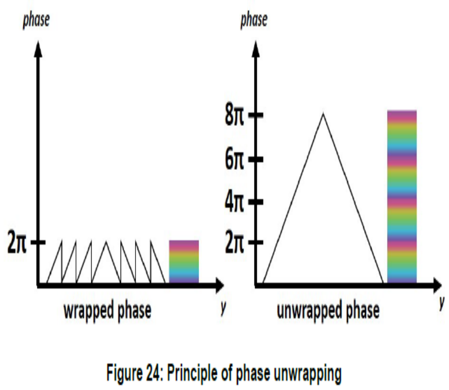


Figure 12: Phase Unwrapping

After obtaining the DEM, the slope, NDVI, RGB images, Label for training are acquired as follows

- **Slope**:The Slope tool identifies the steepness at each cell of a raster surface. The lower the slope value, the flatter the terrain; the higher the slope value, the steeper the terrain[21]. Open the DEM in the arcgis tool and generate slope using "slope" tool in "spatial analyst tools".

- **NDVI**:The normalized difference vegetation index (NDVI) is a simple graphical indicator that can be used to analyze remote sensing measurements and assess the intensity of vegetation. NDVI is an old vegetation index and it is not related to a specific instruments, therefore one can make comparisons in between different instruments/satellites from a wider period of time[22]. Open band4 and band5 data which is downloaded from copernicus in arcis tool and generate NDVI using raster calculator.The formula for calculating NDVI is as follows

$$NDVI = INDEX(B8, B4) = \frac{(B8-B4)}{(B8+B4)}$$

- **RGB Image**: The RGB multispectral image will be readily available in the copernicus open access hub. Download it for the required location

- **Label**:The Label required for training is generated from landslide4sense website [23].The dataset is collected from the challenge in a competition from the portal called Landslide4sense.The Landslide4Sense data consists of the labels representing the landslide susceptibility graphs for various locations.The link for the compition is:
https://www.iarai.ac.at/landslide4sense/challenge. The label is generated by the compitition by considering the following data

  1. Multispectral data from Sentinel-2 B1, B2, B3, B4, B5, B6, B7, B8, B9, B10, B11, B12 bands.
  2. It also includes the Slope data collected from ALOS PALSAR B13 band.
  3. Digital elevation model (DEM) from ALOS PALSAR B14 band.
  4. NDVI data calculated from the band 4 and band 5 of sentinel satellite
  5. Label representing the landslide susceptibility of the considered location

Dataset Pre-Processing
After covering the the whole globe with the generation of DEM, Slope, NDVI and RGB images, we have to preprocess the data set inorder to give it as input to the model.this process is as follows

- **AOI Selection**: from the huge area that is covered by the DEM, Slope, NDVI and RGB image, we need to select different clips for it covering an area of 25-30 square kilometers so as to improve the training the results.

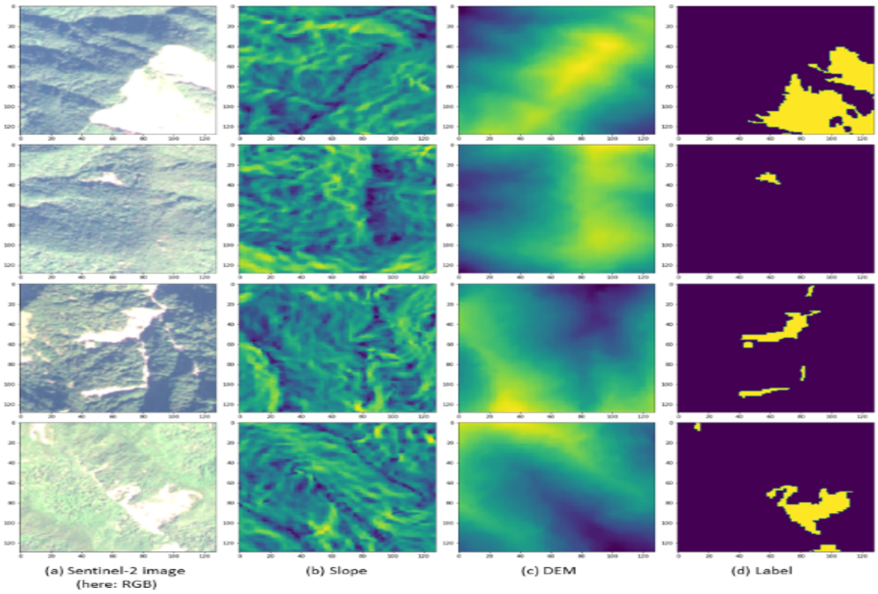


Figure 13: Dataset sample

- **Shape file creation**: Using Google earth pro we can create an .kml file for the area of interest.A KML file is a text file with (among other things) a series of coordinates for creating markers at desired locations[24].From the .kml file we can generate the shape file using arcgis tool with the help of "kml to layer" tool.
- **Clip the AOI**: Using the "extract by mask" tool in arcgis, we can clip the required AOI present in the shapefile from the huge images of DEM, Slope, NDVI, Label and RGB images.
- **Open-CV**: Using Open CV, read these images and store them in a multidimensional array.
- **Finalizing Dataset**: Repeat this process until enough data has been gathered. We have collected 4844 samples, where each sample contain DEM, Slope, NDVI, Label and RGB image.The figure 13 shows the sample dataset made with help of the landslide4sense website and satellite data.

Model Training

The total dataset contains 4844 samples.Train the model using Unet with the dataset created for training after splitting the dataset into train data and test data. After splitting, the train data consists of 3799 samples, test data consists of 800 samples and validation data consists of 245 samples.The U-Net model provides several advantages for segmentation tasks: first, this model allows for the use of global location and context at the same time. Second, it works with very few training samples and provides better performance for segmentation tasks. With the testdata created, we obtained an accuracy of 86%.

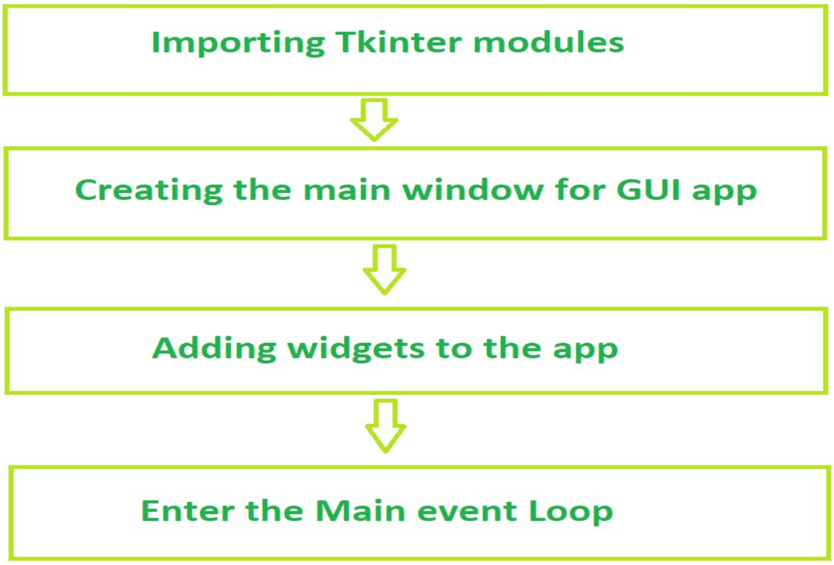


Figure 14: Tkinter Flow

Model Validation
Similar to the process of dataset creation, the DEM,Slope,NDVI, RGB images are generated for the selected study area (i.e) SR-530 landslide and given input to the model. The SR-530 landslide results are obtained and verified.

Graphical User Interface
After the model validation, we moved on to the development of a GUI(Graphical User Interface). When the user upload the four required parameters to the model i.e DEM, Slope, NDVI, RGB Images to the application, The application loads the images and gives the images to the model to predict[25]. The model returns the numpy array representing the prediction results. This numpy array is plotted as a graph and saved as an image to the local disc.After saving, the saved image will be displayed in the Tkinter window using the "PhotoImage" widget available in Tkinter module.Figure 14 represents the flow of a basic Tkinter program.

5.3 Algorithm

This project consists of total six modules. The first module is about analyzing the landslide types and properties. The second module is about dataset obtaining with help of tools like snap tool and arcgis tool along with the data sources like copernicus open access hub, landslide4sense website and alaska satelite facility. The third module is about dataset pre-processing. It involves clipping the created DEM,Slope,NDVI and RGB images with the help of shape files of the Area of interest created from the google earth pro. The fourth module is training using the Unet model. The fifth module is about validating the trained module and the last module is developing the GUI application for it using the Tkinter framwork available in python.

5.3.1 Module-3

Dateset Pre processing
Input : Clipped images from shape files and label
Output: Dataset in form of multidimensional array

1. import cv2 module and matplotlib.image module
2. initialize an empty array ”val” of size (4844,128,128,6) and ”res” array of size (4844,128,128,1)
3. initialize i to 0
4. Traverse through the directory containing the images for each sample
   4.1 read all 4 images using imread() method in image library into an array
   4.2 resize the image into 128*128 size
   4.3 store rgb image at location val[i,:,:,0:2]
   4.4 store ndvi image at location val[i,:,:,3]
   4.5 store slope image at location val[i,:,:,4]
   4.6 store DEM image at location val[i,:,:,5]
   4.7 store label image at location res[i,:,:,:]
   4.8 increment i
5. store the val array and res array
6. initialize ”trainx”, ”trainy” , ”testx”, ”testy”, ”validx”, ”validy” array.
7. assign val[0:3799,:,:,:] to ”trainx” array and res[0:3799,:,:,:] to ”trainy”
8. assign val[3799:4599,:,:,:] to ”testx” array and res[3798:4599,:,:,:] to ”testy”
9. assign val[4599:4844,:,:,:] to ”validx” array and res[0:3798,:,:,:] to ”validy”

5.3.2 Module-4

Training the model
Input : Dataset
Output: Trained Model

1. import required modules
2. define recall, precision, f1 functions.
3. define input shape of image as (128*128)
4. Use ”relu” activation function.
5. create layers in contraction path
6. create layers in expansion path
7. compile the model with ”adam” optimizer and metrics as accuracy, f1, precision, recall.
8. use ModelCheckpoint in callbacks library for earlystopping
9. Fit the model with train data
10. Evaluate the model with test data
11. Obtain the accuracy and loss of the model.

5.3.3 Module-5

Validating the Model
Input : SR-530 Landslide data
Output: Landslide susceptibility of the SR-530 landslide

1. import cv2 module and matplotlib.image module
2. initialize an empty array "val" of size (1,128,128,6)
3. Traverse through the directory containing the images for SR-530
   3.1 read images using imread() method in image library into an array
   3.2 resize the image into 128*128 size
4. store rgb image at location val[0,:,:,0:2]
5. store ndvi image at location val[0,:,:,3]
6. store slope image at location val[0,:,:,4]
7. store DEM image at location val[0,:,:,5]
8. predict val array using predict() method
9. plot the results of label obtained

5.3.4 Module-6

Developing GUI
Input : Model, Data to test
Output: Landslide susceptibility of the region

1. import cv2, matplotlib,Tkinter modules
2. Create a main window for GUI app.
3. Give the window a perfect geometry and a title
4. Create a label and give the project title
5. Create a button and add a function call "upload" associated with it
6. Import the code required to predict the landslide susceptibility from module 4 into the function "upload()"
7. save the plotted graph as an image in to the local disc and return to main event
8. Display the saved image on the screen using a proper widget
9. plot the results of label obtained

6 IMPLEMENTATION

This section represents the implementation part for all the modules involved in our project.

6.1 Output Screen Shots

Module-1 output

Module-1 involves selection of the landslide for analyzing different types of landslide and different properties of landslides. Figure 15 represents the Oso area before the landslide occurrence after the landslide occurrence.

Figure 15: [Oso before and after landslide

Module-2 output

Module-2 involves dataset obtaining for various regions across the globe and generating DEM, Slope, NDVI, RGB images for each required region. Figure 16 represents the DEM,Slope, NDVI, RGB data obtained for the whole city and plotted in python.

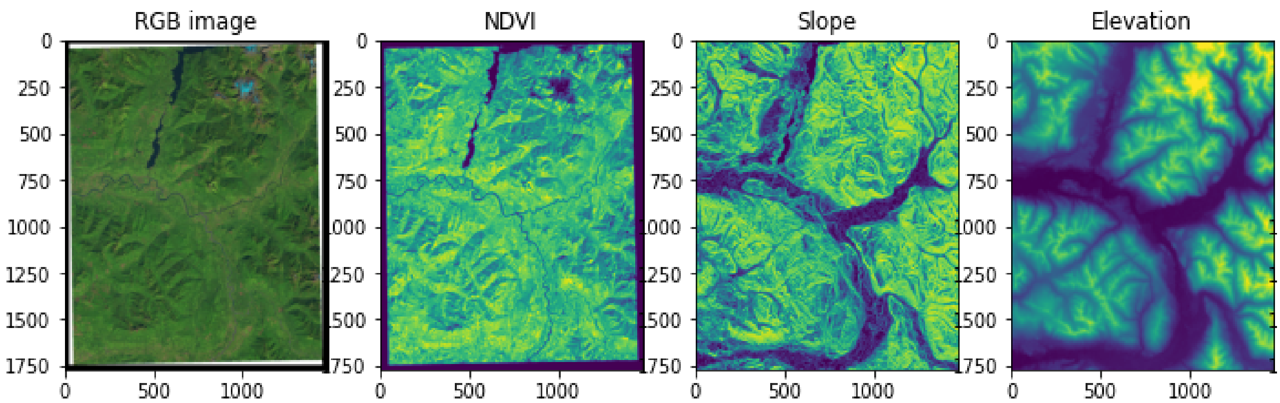


Figure 16: Washington city data

Module-3 output

Module-3 involves dataset pre-processing.Here the data obtained from the previous module is clipped into different segments of similar size and resolution which matches the model requirements. It is done with the help of shape files generated with the help of google earth pro. Figure 17 represents the clipped area from the huge area data using the area's shapefile. The shapefile will be difficult to visualize because it is just a layer file.

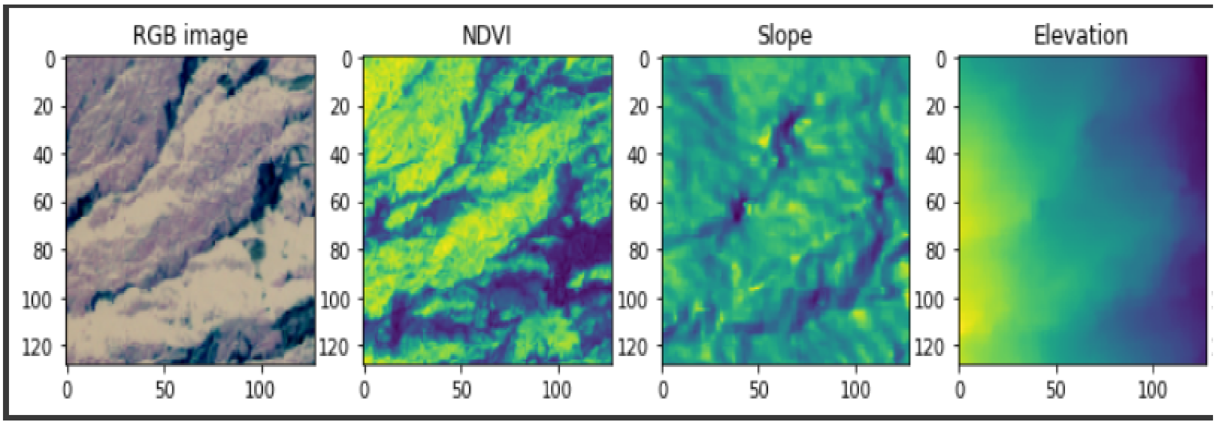
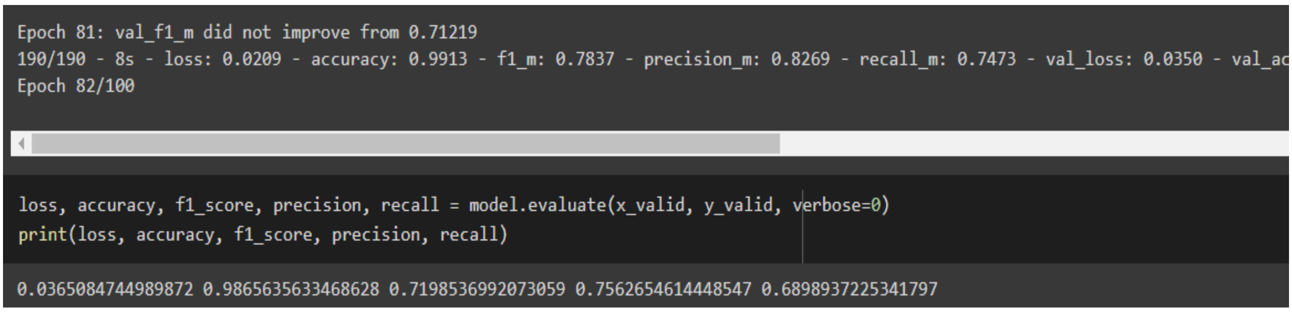


Figure 17: Clipped data

Module-4 output

The fourth module involves training the Unet model with the dataset created. The training involves the usage of metrics like accuracy, precision, f1, recall. The training is done by following the Unet Architecture. The model consists of contraction and expansion paths. The dataset is split into train data, valid data and test data. The model is trained using train data. The model is tested using test data and obtained the accuracy and loss. The model is compiled with "adam" optimizer. The training results in 98% accuracy, 75% prescision and 3.6% loss. Figure 18 represents the results of training



```
Epoch 81: val_f1_m did not improve from 0.71219
190/190 - 8s - loss: 0.0209 - accuracy: 0.9913 - f1_m: 0.7837 - precision_m: 0.8269 - recall_m: 0.7473 - val_loss: 0.0350 - val_ac
Epoch 82/100

loss, accuracy, f1_score, precision, recall = model.evaluate(x_valid, y_valid, verbose=0)
print(loss, accuracy, f1_score, precision, recall)

0.0365084744989872 0.9865635633468628 0.7198536992073059 0.7562654614448547 0.6898937225341797
```

Figure 18: Training output

Module-5 output

The fifth module is about validating the model. This involves generating the DEM, Slope, NDVI, RGB images for the SR-530 landslide and giving input to the model. It involves verifying the results and finalizing the model prediction accuracy. Figure 19 shows the data of the SR-530 landslide. Figure 20 shows the prediction of SR-350 landslide by the model.

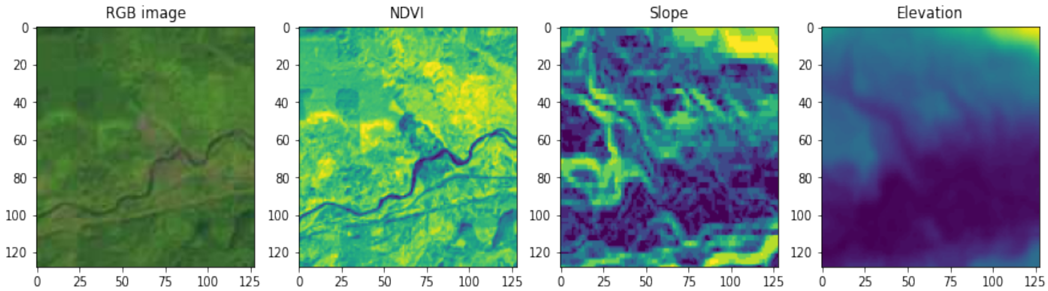


Figure 19: SR-530 Data

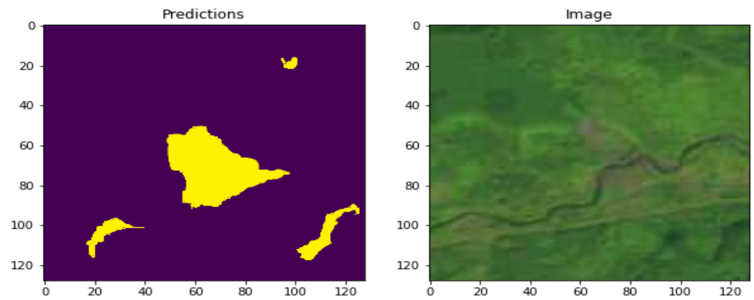


Figure 20: SR-530 output

The model is tested on other samples too inorder to check the behaviour of the model. The Figure 21 represents the sample-1 location's DEM, Slope, NDVI, RGB Images which are the inputs to the model and also the model predicted mask.

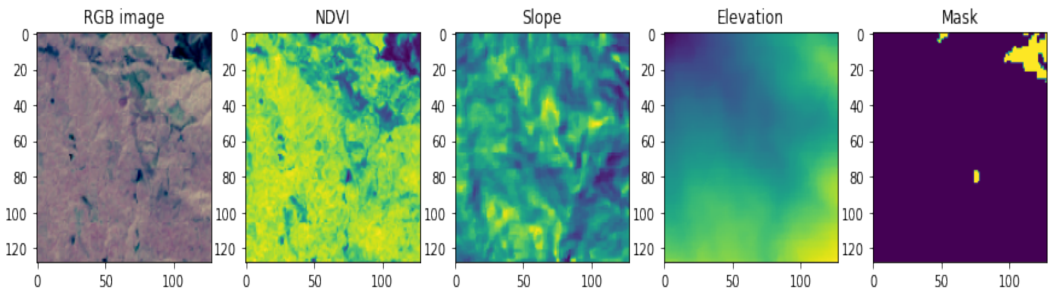


Figure 21: sample-1 output

The Figure 22 represents the sample-2 location's input parameter along with the model predicted mask.

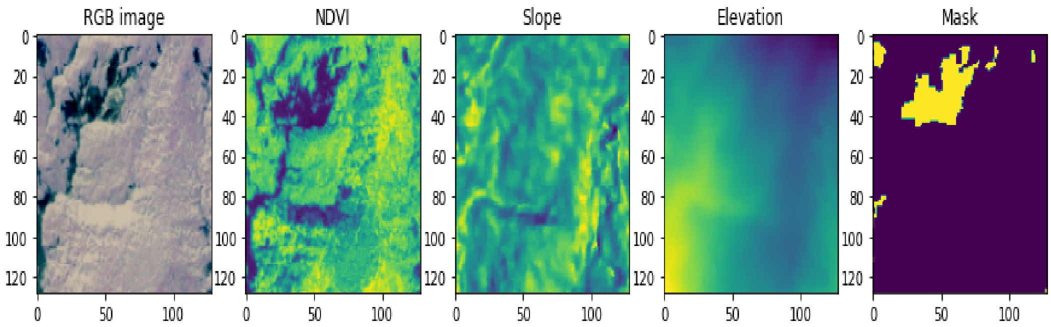


Figure 22: sample-2 output

The Figure 23 represents the sample-3 location's input parameter along with the model predicted mask.

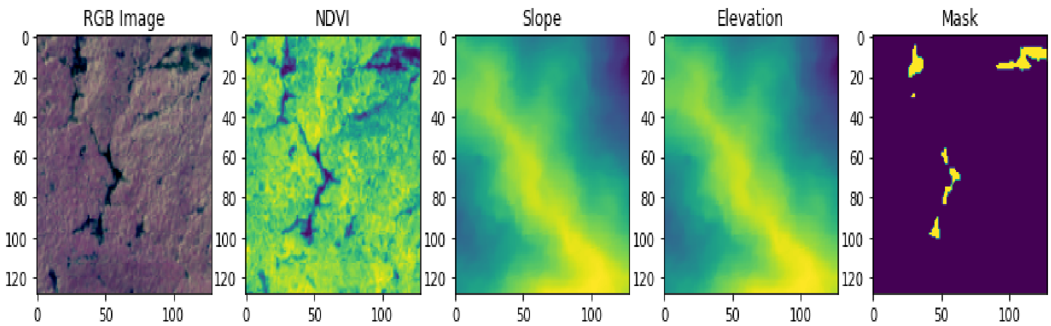


Figure 23: sample-3 output

The Figure 24 represents the sample-4 location's input parameter along with the model predicted mask.

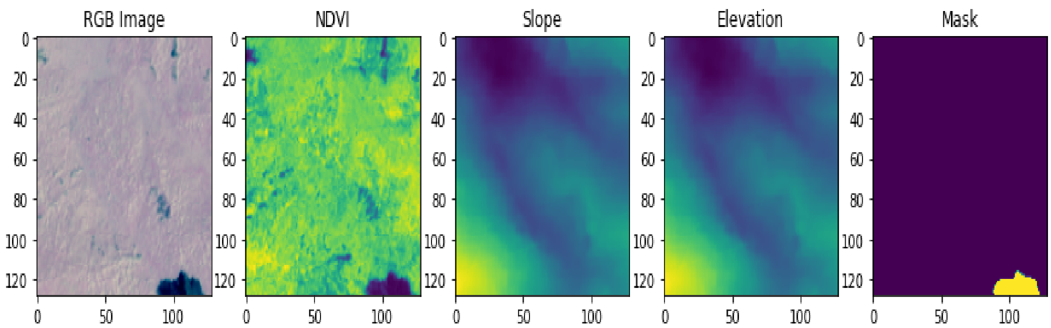


Figure 24: sample-4 output

Module-6 output

Tkinter is the de facto way in Python to create Graphical User interfaces (GUIs) and is included in all standard Python Distributions. Tkinter provides various controls, such as buttons, labels and text boxes used in a GUI application called widgets.All Tkinter widgets have access to specific geometry management methods. Tkinter Application is developed keeping in view the portability feature. Figure 25 represents the developed GUI Application.

Figure 25: GUI Application

6.2 Result And Analysis

For the developed GUI Application, the user will give the four required images as input. The application will read the path of the images selected and loads them. Figure 26 describes the process of selecting the required images in proper format for giving input to the application

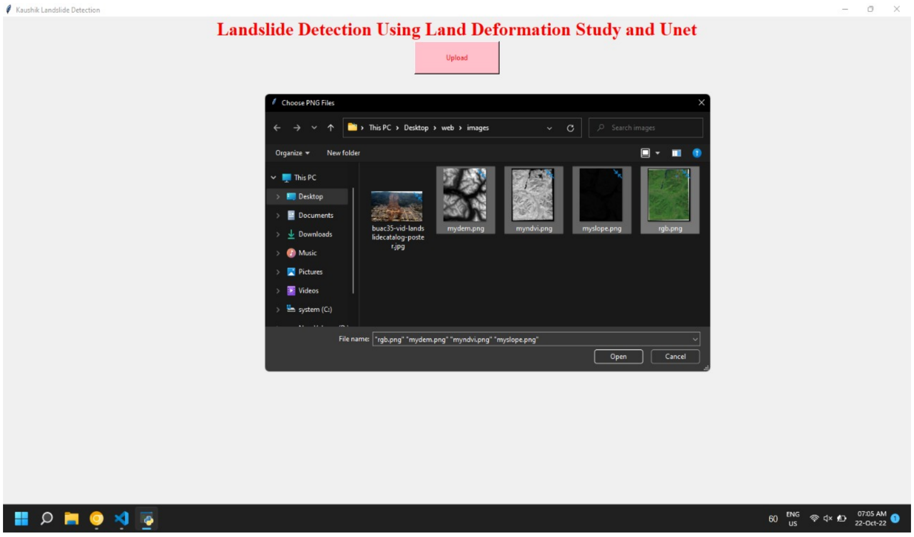


Figure 26: Proving input to Application

After loading the images, The application will call a function called "upload()". In this upload function the logic necessary to predict the images will reside. The images will be given as input to the model and the predicted as result of form numpy array will be returned. The numpy array will be plotted as a graph and saved as a .png image into the local disc. The saved images will be displayed on the window using the "PhotoImage" widget. Figure 27 shows the result of the GUI Application.

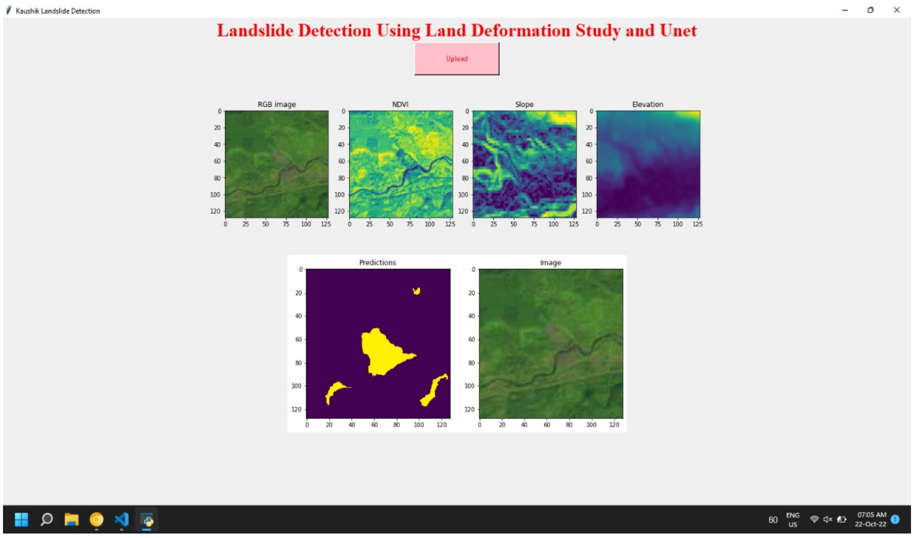


Figure 27: Application output

7 TESTING

This chapter includes the testing of the proposed system.

7.1 Test Case I: Validating the model with validation data

<table>
<tr><td colspan="7">Project Name: DETECTION AND PREDICTION OF LANDSLIDE VULNERABILITY THROUGH LAND DEFORMATION STUDY USING DINSAR AND DEEP LEARNING TECHNIQUES</td></tr>
<tr><td colspan="3">Test case Id: 1</td><td colspan="4">Test Designed By: Vishnu</td></tr>
<tr><td colspan="3">Test Priority: High</td><td colspan="4">Test Designed Date: 10-10-2022</td></tr>
<tr><td colspan="4">Module Name: Computer Vision and DL</td><td colspan="3">Test Executed By: Vishnu</td></tr>
<tr><td colspan="5">Test Title: Verifying the model behaviour with Valid data</td><td colspan="2">Test Executed Date:10-10-2022</td></tr>
<tr><td colspan="7">Description:Verifying the model behaviour upon providing the validation data.</td></tr>
<tr><td colspan="7">Pre-Conditions: User should contain all four required parameters</td></tr>
<tr><td>Stage</td><td>Test Steps</td><td>Test Data</td><td>Expected Result</td><td>Actual Result</td><td>Status</td><td>Remarks</td></tr>
<tr><td>1</td><td>Providing the images to model</td><td>Data from validation folder</td><td>Landslide susceptibility of that region</td><td>Landslide susceptibility of that region</td><td>Pass</td><td>Nil</td></tr>
<tr><td>2</td><td>Verifying the model output with RGB image</td><td>Data from satellite images and model output</td><td>Matching extent of the landslide markings</td><td>Matching extent of the landslide markings</td><td>Pass</td><td>Nil</td></tr>
<tr><td colspan="7">Post-Conditions:Verifying the model behaviour with validation data should be successful</td></tr>
</table>

(1)

7.2 Test Case II: Validating the model behaviour with manually generated study area data.

Project Name: DETECTION AND PREDICTION OF LANDSLIDE VULNERABILITY THROUGH LAND DEFORMATION STUDY USING DINSAR AND DEEP LEARNING TECHNIQUES						
Test case Id: 2			Test Designed By: Kaushik			
Test Priority: High			Test Designed Date: 15-10-2022			
Module Name: Remote Sensing				Test Executed By: Kaushik		
Test Title: Verifying model behaviour for study area					Test Executed Date:15-10-2022	
Description:Verifying the model behaviour upon proving the manually generated study area's data						
Pre-Conditions: User should have all four required parameters						
Stage	Test Steps	Test Data	Expected Result	Actual Result	Status	Remarks
1	Provides images as input	Data from satellite images	Landslide susceptibility of study area	Landslide susceptibility of study area	Pass	Nil
2	Verifying the model output actual landslide image	Data from satellite images and model output	Matching extent of the landslide markings	Matching extent of the landslide markings	Pass	Nil
Post-Conditions: model behaviour verification with manually generated data should be successful						

(2)

7.3 Test Case III: Testing the Tkinter Application

Project Name: DETECTION AND PREDICTION OF LANDSLIDE VULNERABILITY THROUGH LAND DEFORMATION STUDY USING DINSAR AND DEEP LEARNING TECHNIQUES						
Test case Id: 3			Test Designed By: Kaushik			
Test Priority: High			Test Designed Date: 20-10-2022			
Module Name: Computer Vision and DL				Test Executed By: Kaushik		
Test Title: Testing the Tkinter Application				Test Executed Date:20-10-2022		
Description:Testing the behaviour of the application in various cases.						
Pre-Conditions: User should contain all four required parameters in proper format						
Stage	Test Steps	Test Data	Expected Result	Actual Result	Status	Remarks
1	Providing the images to application	Data with user	Landslide susceptibility of that region	Landslide susceptibility of that region	Pass	Nil
2	less than four images uploaded	Data with user	Displays error message	Displays error message	Pass	Nil
3	Wrong image format uploaded	Data with user	Displays warning message	Displays warning message	Pass	Nil
4	Different sized images uploaded	Data with user	Displays warning message	Displays warning message	Pass	Nil
Post-Conditions:The behaviour of the application should be satisfactory						

(3)

8 CONCLUSION AND FUTURE WORK

There are various causes for the landslide like rainfall, deforestation, human interventions etc. Landslide is a natural disaster which may be caused at any time and by any cause. It will be hardly impossible to detect the landslide before it shows any of its signature. So, with remote sensing and deep learning we can solve this problem to some extent. Before any landslide occurs, some deformations can be observed on the Earth's topography. By analysing the deformation patterns of various landslides, we can predict the fore-coming landslide if it starts showing its signature. For this, the continuous monitoring of the location is required. If a landslide pattern is identified, immediately an alert can be made by the local government to the commuters. For landslide detection, we need to observe the slope, elevation, vegetation index of the location. Based on the acquired results, we can find the landslide susceptibility of the location.

The future work includes finding the landslide susceptibility with both remote sensing and optical image analysis with help of drones revolving around the required area. The model can be made more accurate by using some other advanced architectures. More parameters can be added as a part of landslide detection for accurate results along with DEM, Slope, NDVI and RGB image.

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