CHAPTER 1

INTRODUCTION

Disasters cripple a population and bring catastrophical changes in the lives of thousands and sometimes millions. Even though disasters cannot be prevented from happening, necessary and precautionary steps can be taken by learning lessons from past disasters to be better prepared for the future. Understanding the actual effect that a disaster has on a state is one of the most challenging activity an administration needs to undertake. Current methods rely heavily on windshield surveys but these do not always reflect the ground reality owing to human error, misjudgement and miscalculations.

With the rapid advancement in technology, and those in Computer Vision and Machine Learning particularly, the practices in image processing and deep learning can be employed to accurately and efficiently analyze the aftermath of a disaster on a state. By using the practices of extracting information from available data, we can estimate and understand the quantified loss. Data Science is one of the most exciting interdisciplinary emerging fields that has the potential to solve all kinds of problems humanity faces. It helps us to perceive and scrutinize actual phenomena, and also describes factors that are the causes of various issues and the factors that guide/lead us to the solutions. It is rightfully termed to be the fourth paradigm of science.

In recent years, satellite systems and image analysis techniques have developed to an extent where civil and commercial Earth observation instruments can contribute significantly to support the management of major technical and natural disasters as well as humanitarian crisis situations. Comparing today’s availability of satellite imagery to the situation ten years ago, the amount, timeliness and availability of satellite imagery covering a certain crisis situation or disaster event has improved substantially. Hence, the analysis of satellite images is supposedly playing an increasingly vital role in environment and climate monitoring, especially in detecting and managing natural disasters like floods.

Beginning on 15 August 2018, severe floods affected the state of Kerala, due to unusually high rainfall during the monsoon season. It was the worst flood in Kerala in nearly a century. About a million people were evacuated. All 14 districts of the state were placed on red alert. According to the Kerala government, one-sixth of the total population of Kerala had been directly affected by the floods and related incidents. The Indian government had declared it a Level 3 Calamity, or "calamity of a severe nature". It was the worst flood in Kerala after the great flood of 99 that took place in 1924. Due to the increased availability of satellite imageries and the know hows of the technology, efforts can be put to better analyse the 2018 floods of Kerala. The study will help us understand the effects and also be more prepared for any occurrence in future.

One way of addressing this problem statement would be to undertake the image classification problem. Ground based imagery analytics has benefited abundantly from extensive research and experimentation, especially with the help of open source datasets such as PASCAL-VOC, MS COCO and ImageNet. But similar efforts still lack in the case of overhead imageries. Certain unique challenges associated with satellite imageries such as low training sample frequency and high dimensionality act as hurdles that can only be addressed by making algorithmic contributions to the proposed approaches. Recent well received initiatives including SpaceNet have tried to address this issue and the analytics of remote sensing images is still a relatively under-researched part of the Machine Learning community's collective effort. Remote Sensing Image Classification is a challenge found at the intersection of the developing field of Computer Vision and Remote Sensing Imagery Analytics. Efforts can be put in building models or using already existing models that help in classification and then perform the analysis and insight extraction.

One such recently devised and sophisticated model is U-Net and it’s variant - TernausNet. U-Net model was built for semantic segmentation of images with the intent of build detection. Image segmentation was revolutionized by the use of deep convolutional neural networks and is one of the most complex task in computer vision. The TernausNet is a model trained on a set of two-dimensional satellite images. The corresponding labels are binary masks, ie. two-dimensional matrices with ones for pixels where a building was present, zeros otherwise. Given a satellite image as input, the network is then able to output a corresponding predicted binary mask. This model can be used for damaged/washed away building detections that can help to infer the estimated property/monetary loss caused to the state and its people. Architectural damage can also give a clear indication about the extent/intensity of disaster caused to the state.

CHAPTER 2

PROBLEM STATEMENT

OBJECTIVE

The primary objective of our project is to analyse the effect of the Kerala floods of 2018 over the state. We also hope to gain a deeper understanding of various computer vision techniques, state-of-the-art deep neural networks and their applications over satellite imageries.

MOTIVATION

With recent news of the havoc caused in the state due to environmental changes and also rapid advancement in technology, we felt it was crucial to study climate change and Earth’s response to it. Our motivation to take up this field of study hence includes the recent Kerala flood disaster and also climate change in general. Satellite imageries are data sets that can help us study the climate in an extremely democratized way and also help in many ways for various applications. Deep Learning and Computer Vision techniques can help us understand, scrutinize and gain insights from these data sets in a very efficient and accurate way. Coincidentally, analysis of remote sensing imagery using deep learning techniques is also a relatively under-researched in the Machine Learning community and hence there is a lot of scope for research.

PROBLEM STATEMENT -

Analysing Satellite Imagery, by implementing one of the advanced deep learning techniques, for the purpose of monitoring ‘Kerala floods’, with best possible accuracy and deducing meaningful insights for flood response & mitigation such as identification of regions gravely affected, spatial extent of inundation, flood damage statistics and improving preparedness for future possibilities of any potentially catastrophic floods such as identification of chronically flood prone areas and optimum geographic spaces for evacuation shelters.

CHAPTER 3

SURVEY OF LITERATURE

1. Vladimir I. Iglovikov, Selim Seferbekov, Alexander V. Buslaev, Alexey Shvets : TernausNetV2: Fully Convolutional Network for Instance Segmentation. arXiv preprint arXiv:1806.00844 [cs.CV] (2018)

This paper presents TernausNetV2 - a fully convolutional network that allows extracting objects from a high-resolution satellite imagery on an instance level. The network has popular encoder-decoder type of architecture with skip connections but has a few essential modifications that allows using for semantic as well as for instance segmentation tasks. This approach is universal and allows to extend any network that has been successfully applied for semantic segmentation to perform instance segmentation task. In addition, network encoder that was pre-trained for RGB images to use additional input channels is generalized. It makes possible to use transfer learning from visual to a wider spectral range. For DeepGlobe-CVPR 2018 building detection sub-challenge, based on public leaderboard score, this approach shows superior performance in comparison to other methods. The source code and corresponding pre-trained weights are publicly available.

2. Z. Zhang, Q. Liu and Y. Wang, "Road Extraction by Deep Residual U-Net," in IEEE

Geoscience and Remote Sensing Letters, vol. 15, no. 5, pp. 749-753, May 2018.

doi: 10.1109/LGRS.2018.2802944

This paper introduces a Residual U-Net for road detection purposes and also exhibits how and why U-Net has been so extremely successful for this use-case. In the paper, a semantic segmentation neural network which combines the strengths of residual learning and U-Net is proposed for road area extraction. The network is built with residual units and has similar architecture to that of U-Net. The benefits of this model is two-fold: first, residual units ease training of deep networks.

Second, the rich skip connections within the network could facilitate information propagation, allowing us to design networks with fewer parameters however better performance. The authors have tested the network on a public road dataset and compared it with U-Net and other two state of the art deep learning based road extraction methods. The proposed approach outperforms all the comparing methods, which demonstrates its superiority over recently developed state of the arts.

3. V. Badrinarayanan, A. Kendall and R. Cipolla, "SegNet: A Deep Convolutional Encoder-

Decoder Architecture for Image Segmentation," in IEEE Transactions on Pattern Analysis

and Machine Intelligence, vol. 39, no. 12, pp. 2481-2495, 1 Dec. 2017.

doi: 10.1109/TPAMI.2016.2644615

This paper helped us to understand the encoder-decoder architecture that U-Net consists of. The paper proposes SegNet, a novel and practical deep fully convolutional neural network architecture for semantic pixel-wise segmentation. This core trainable segmentation engine consists of an encoder network, a corresponding decoder network followed by a pixel-wise classification layer. The architecture of the encoder network is topologically identical to the 13 convolutional layers in the VGG16 network. The role of the decoder network is to map the low resolution encoder feature maps to full input resolution feature maps for pixel-wise classification. The novelty of SegNet lies is in the manner in which the decoder upsamples its lower resolution input feature map(s). Specifically, the decoder uses pooling indices computed in the max-pooling step of the corresponding encoder to perform non-linear upsampling. This eliminates the need for learning to upsample. The upsampled maps are sparse and are then convolved with trainable filters to produce dense feature maps.

4. Y. Bentoutou, N. Taleb, K. Kpalma and J. Ronsin, "An automatic image registration for

applications in remote sensing," in IEEE Transactions on Geoscience and Remote Sensing,

vol. 43, no. 9, pp. 2127-2137, Sept. 2005.

doi: 10.1109/TGRS.2005.853187

This paper deals with a major problem encountered in the area of remote sensing consisting of the registration of multitemporal and/or multisensor images. In general, such images have different gray-level characteristics, and simple techniques such as those based on correlation cannot be applied directly. In this work, a new automatic satellite image registration approach is proposed. This technique exploits the invariant relations between regions of a reference and a sensed image, respectively. It involves an edge-based selection of the most distinctive control points (CPs) in the reference image.

The search for the corresponding CPs in the sensed image is based on local similarity detection by means of template matching according to a combined invariants-based similarity measure. The final warping of the images according to the selected CPs is performed by using the thin-plate spline interpolation. The procedure is fully automatic and computationally efficient. The proposed algorithm for this technique has been successfully applied to register multitemporal SPOT and synthetic aperture radar images from urban and agricultural areas. The experimental results demonstrate the robustness, efficiency and accuracy of the algorithm.

5. IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG)

e-ISSN: 2321–0990, p-ISSN: 2321–0982.Volume 1, Issue 2 (Jul. –Aug. 2013), pp 01-10

www.iosrjournals.org

6. C. Wu, B. Du, X. Cui and L. Zhang, "A post-classification change detection method based

on iterative slow feature analysis and Bayesian soft fusion", Remote Sensing of

Environment, vol. 199, pp. 241-255, 2017.

Post-classification with multi-temporal remote sensing images is one of the most popular change detection methods, providing the detailed “from-to” change information in real applications. However, due to the fact that it neglects the temporal correlation between corresponding pixels in multi-temporal images, the post-classification approach usually suffers from an accumulation of misclassification errors. In order to solve this problem, previous studies have separated the change and non-change candidates with change vector analysis, and they have only updated the classes of the changed pixels with the post-classification; however, this approach with thresholding loses the continuous change intensity information, where larger values indicate higher probability to be changed. Therefore, in this paper, a new post-classification method with iterative slow feature analysis (ISFA) and Bayesian soft fusion is proposed to obtain reliable and accurate change detection maps. The proposed method consists of three main steps: 1) independent classification is implemented to obtain the class probability for each image; 2) the ISFA algorithm is used to obtain the continuous change probability map of multi-temporal images, where the value of each pixel indicates the probability to be changed; and 3) based on Bayesian theory, the a posteriori probabilities for the class combinations of coupled pixels are calculated to integrate the class probability with the change probability, which is named as Bayesian soft fusion. The class combination with the maximum a posteriori probability is then determined as the change detection result.

7. Mahesh and M. V. Subramanyam, "Automatic feature based image registration using SIFT algorithm," *2012 Third International Conference on Computing, Communication and Networking Technologies (ICCCNT'12)*, Coimbatore, 2012, pp. 1-5.

doi: 10.1109/ICCCNT.2012.6396024

Image registration is the process of mapping and geometrically aligning the two or more images. The steps in image registrations include: feature detection, feature matching and image transformation, and resampling. The accuracy of a registration process is highly dependent on the feature detection and matching. In this paper, we use a SIFT (Scale Invariant Feature Transform) algorithm to detect features, which is invariant to rotation, scaling and noise. Then initial matching is computed using Euclidean distance, and mismatch features between point pairs are eliminated using RANSAC. The result shows that the automatic registration algorithm is correct and effective.

8. Jwan Al-doski, Shattri B. Mansor, Helmi Zulhaidi Mohd Shafri, "Change Detection Process and Techniques", Civil and Environmental Research, vol. 3, no. 10, 2013, ISSN 2224-5790.

This paper looks into the following aspects related to the remote sensing technology - change detection process and techniques for land cover changes, and factor affecting change detection techniques and considerations.

9. S. Voigt, T. Kemper, T. Riedlinger, R. Kiefl, K. Scholte and H. Mehl, "Satellite Image Analysis for Disaster and Crisis-Management Support," in IEEE Transactions on Geoscience and Remote Sensing, vol. 45, no. 6, pp. 1520-1528, June 2007.  
doi: 10.1109/TGRS.2007.895830

This paper describes how multisource satellite data and efficient image analysis may successfully be used to conduct rapid-mapping tasks in the domain of disaster and crisis-management support. This paper describes successful rapid satellite mapping campaigns supporting disaster relief and demonstrates how this technology can be used for civilian crisis-management purposes. During the last years, various international coordination bodies were established, improving the disaster-response-related cooperation within the Earth-observation community worldwide.

This paper reflects on several of these international activities, such as the International Charter Space and Major Disasters, describes mapping procedures, and reports on rapid-mapping experiences gained during various disaster-response applications.

10. L. Giustarini, R. Hostache, P. Matgen, G. J. -. Schumann, P. D. Bates and D. C. Mason, "A Change Detection Approach to Flood Mapping in Urban Areas Using TerraSAR-X," in IEEE Transactions on Geoscience and Remote Sensing, vol. 51, no. 4, pp. 2417-2430, April 2013.  
doi: 10.1109/TGRS.2012.2210901

Enhanced image processing algorithms and a better exploitation of image archives are required to facilitate the use of microwave remote-sensing data for monitoring flood dynamics in urban areas. In this paper, a hybrid methodology combining backscatter thresholding, region growing, and change detection (CD) is introduced as an approach enabling the automated, objective, and reliable flood extent extraction from very high resolution urban SAR images.

CHAPTER 4

REQUIREMENTS ANALYSIS

ARCHITECTURAL AND DESIGN REQUIREMENTS

The project would require various phases in the model, each with it’s own functionality. We have identified three phases namely - image registration, classification and difference detection.

Analysis :

The design/architecture is

(i) Modular (atomic) - Each phase has non-overlapping and individual functionality

(ii) (Each phase is ) Uniquely identified

(iii) Consistent and Unambiguous - Each phase has a distinct functionality

(iv) Testable - Each phase can be tested depending on accuracy, output values and known expected values

SYSTEM AND INTEGRATION REQUIREMENTS

The system comprises of phases which are pipelined linearly, ie., the output of image the first (registration) phase is fed into the input of the next phase namely classification, etc. For the implementation of the system, we require online cloud services including GPU and High Performance Computing services.

Analysis :

The system and integration of the project is

(i) Complete - Each system integration has its own specific contribution to the overall working of the project

(ii) Consistent and Unambiguous

(iii) Traceable

(iv) Testable