Satellite Based Damage Mapping Using U-net Convolutional Network

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Abstract- **Satellite remote-sensing-based damage-mapping technique has played an indispensable role in rapid disaster response practice. The current disaster response practice remains subject to the low damage assessment accuracy and lag in timeliness, which dramatically reduces the significance and feasibility of extending the present method to practical operational applications. Therefore, a highly efficient and intelligent remote-sensing image-processing framework is urgently required to mitigate these challenges. In this paper, a deep learning algorithm for the semantic segmentation of high-resolution remote-sensing images using the U-net convolutional network is proposed to map the damage rapidly.**

Keywords U-Net, convolutional network, Satellite images, Damage mapping

I. Introduction

In recent years, mega natural disasters such as the 2011 Tohoku Earthquake-Tsunami and 2004 Sumatra Earthquake Tsunami have frequently hit the world [1, 2, 3] and are considered some of the primary tremendous and tragic threats to the safety of human life and property [4]. The increased awareness of the role of rapid damage assessment in post-disaster response to reduce the damage losses and casualties has raised much attention in implementing satellite-based methods to monitor the disaster damage information [5]. Considering the high timeliness requirements of disaster emergency response, high-precision and efficient damage estimation methods at a fine scale to support the response are urgently required.

In this article, a deep learning algorithm for the semantic segmentation of high-resolution remote-sensing images using the U-net convolutional network is proposed to map disaster damage rapidly. The algorithm was implemented using keras library in python programming language. The study takes the xView2 Challenge Dataset as a case study, for which the pre- and post-disaster high-resolution images are used. The implementation of streamlined, efficient damage assessment is critical in operational disaster response. There is an ongoing lag with existing damaged assessment methods considering the timeliness and accuracy [5]. To grasp the damage situation, the current practice largely relies on the field survey and social media report. Since late 2017, DigitalGlobe's open data program has provided a dedicated stream of accurate high-resolution satellite imagery to support large-scale disaster response activities worldwide [6], which provides a good opportunity for developing a satellite-based method to map the damage. Visual interpretation of the damage from the satellite imagery has been widely used in practice for damage assessment for a long time because of its high precision [7, 8]. However, this method is time-consuming, particularly if the affected areas are notably large.

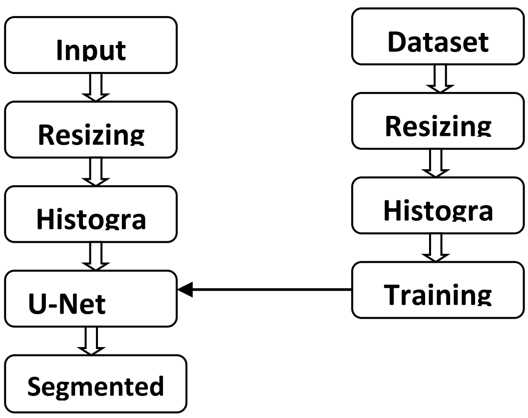
II. The Existing System

Complexity and uncertainty in many practical problems require new methods and tools. Image processing is one of these tools that can be used as an efficient process for greater rewards. Further attention towards post disaster emergency response is well justified to make urban areas more disaster-safe. Hence, getting real-time information of damaged urban surfaces rapidly and accurately after a natural disaster is extremely useful for response processes [4, 5]. Li et al. studied network environment by looking at trading volume and asset price risk when sentimental data was available using both sentiment analysis and popular machine learning approaches in the disaster assessment [6]. Anderson and Davison considered the applications of an innovative spot price model to risk management in electricity markets [7]. Choi and Lee discuss using regional innovation systems for sustainable economic development [8]. Wei et al. propose a framework to assess disasters' social impacts based on network information resources [9].

III. Proposed Method

We propose a U-Net-Architecture model for damage classification and building segmentation. One element of this architecture is a U-Net model that analyzes a single input image and produces a segmentation mask showing building locations in the input image. The U-Net model is a fully convolutional network that was proposed by Ronneberger et al. [10] for image segmentation. Besides its encoder-decoder structure for local information extraction, it also utilizes skip connections to retain global information. A single U-Net model analyzes input frames IA and IB, which depict the same scene pre-disaster and post-disaster, respectively. Since the U-Net focuses on the building segmentation objective, it is agnostic to the disaster. In other words, we can use the same model for both pre-disaster and post-disaster images to produce binary masks IMA and IMB, corresponding to their respective input frames. The two green regions indicate the shared U-Net model for IA and IB.

The features extracted from the encoder regions of the U-Net model also assist in the damage scale classification task. The two-stream features produced by the U-Net encoder and a new, separate decoder constitute the Siamese network, shown as the blue region. In the Siamese network, we compare features from the two input frames to detect the damage levels of buildings. Simple differencing and channel-wise concatenation are two methods to compare the two-stream features. By comparing features from the two frames, the model evaluates the differences between the features in order to assess the damage levels.



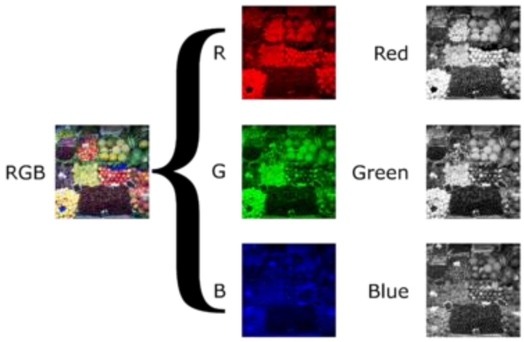


Figure 1. RGB in Images

IV. Image Processing

Image processing is a process that tries to create a new picture as a result of changing the view and attributes of the real-life images that are become numerical picture.

Grayscale images are distinct from one-bit bi-tonal black-and-white images, which, in the context of computer imaging, are images with only two colors: black and white (also called bi-level or binary images). Grayscale images can be the result of measuring the intensity of light at each pixel according to a particular weighted combination of frequencies (or wavelengths), and in such cases they are monochromatic proper when only a single frequency (in practice, a narrow band of frequencies) is captured. The frequencies can in principle be from anywhere in the electromagnetic spectrum (e.g. infrared, visible light, ultraviolet, etc.).

Satellite Image Processing is an important field in research and development and consists of the images of earth and satellites taken by the means of artificial satellites. The photographs are taken in digital form and later are processed by the computers to extract the information. Statistical methods are applied to the digital images and after processing the various discrete surfaces are identified by analyzing the pixel values.

Histogram equalization is applied on a grayscale image. It can also be used on color images by applying the same method separately to the Red, Green and Blue components of the RGB color values of the image. Applying the same method on the Red, Green, and Blue components of an RGB image may yield dramatic changes in the image's color balance since the relative distributions of the color channels change as a result of applying the algorithm. If the image is first converted to another color space, Lab color space, or HSL/HSV color space in particular, then the algorithm can be applied to the luminance or value channel without resulting in changes to the hue and saturation of the image [4]. There are several histogram equalization methods in 3D space. Trahanias and Venetsanopoulos applied histogram equalization in 3D color space.

V. The U-Net Architecture

U-NET was developed by Olaf Ronneberger et al. for Bio Medical Image Segmentation. The architecture contains two paths. First path is the contraction path (also called as the encoder) which is used to capture the context in the image. The encoder is just a traditional stack of convolutional and max pooling layers. The second path is the symmetric expanding path (also called as the decoder) which is used to enable precise localization using transposed convolutions. Thus it is an end-to-end fully convolutional network (FCN), i.e. it only contains Convolutional layers and does not contain any Dense layer because of which it can accept image of any size.

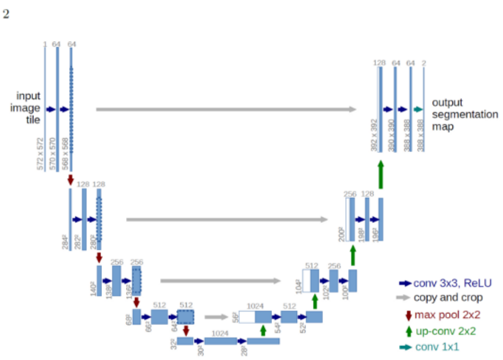


Figure 2. The U-Net Architecture

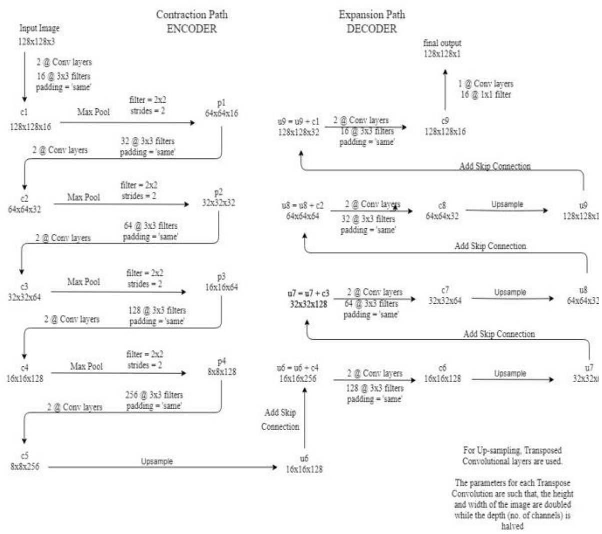


Figure 3. Stages from Input to Output

VI. Implementation and Results

Figure 4. Comparison: Before and after disaster

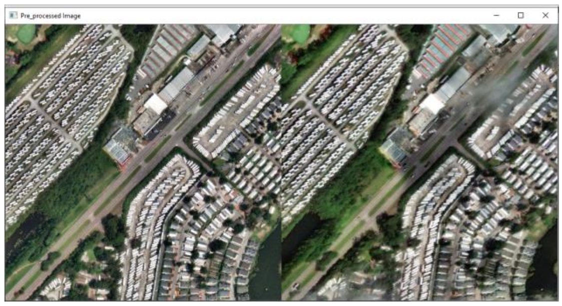


Figure 5. Enhanced Image

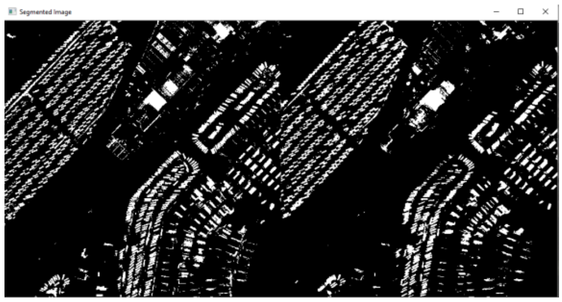


Figure 6. U-Net Segmented Image

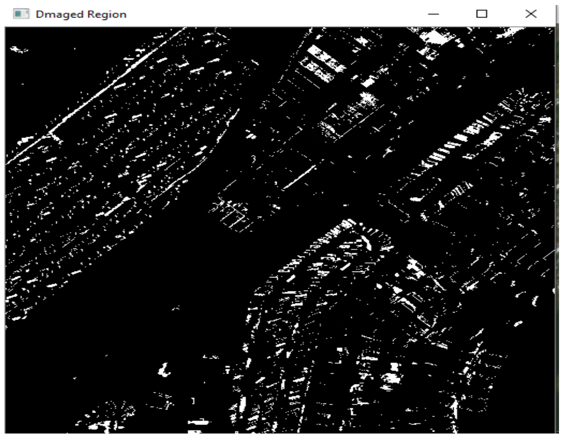


Figure 7. Comparison: before and after disaster

VII. Conclusion

This paper presents a U-Net model with self-attention for building segmentation and damage scale classification in satellite imagery. The proposed technique compares pairs of images captured before and after disasters to produce segmentation masks that indicate damage scale classifications and building locations. Results show that the proposed model accomplishes both damage classification and building segmentation more accurately than other approaches with the xView2 dataset. We use the self-attention module to enhance damage scale classification by considering information from the entire image.

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