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Comparative Study of Change Detection Methods in High-resolution Images

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Abstract

Natural phenomena, including weathering, erosion, volcanic eruptions, and plate tectonics, as well as human activities like agriculture, deforestation, and urbanization, cause the Earth's surface to change continuously. In many different applications, such as environmental monitoring, disaster management, urban planning, agriculture and forestry, climate change studies, resource management, and infrastructure monitoring, it may be extremely beneficial to detect and track these changes. There are various algorithms and methods proposed by many researchers, which can detect the changes by comparing the images captured at different times. In this paper, a comparison of various change detection methods using images processing has been made and their performance has been compared on the basis of various parameters like accuracy, kappa coefficients, false alarms, etc. Change detection in high-resolution photos has drawn a lot of interest because it can be used in a variety of scenarios, including environmental monitoring, urban planning, and disaster relief. A comparison of several change detection techniques applied to high-resolution images is presented in this article. We explore the workings, elements, and uses of different approaches, emphasizing their advantages and disadvantages. A thorough conclusion on the best use of each strategy is provided after providing insights into the efficiency of these techniques in various settings in the discussion section.

Keywords: Discrete wavelet transform, climate change, kappa coefficients, discrete wavelet transform, image clustering method

INTRODUCTION

The Earth's surface is constantly changing due to a variety of natural and human-caused processes, which emphasizes the significance of efficient change detection techniques [1]. For a variety of applications, including resource allocation, urban planning, disaster management, and environmental protection, monitoring and comprehension of these changes are essential. Numerous change detection algorithms with distinct methods for examining Earth observation data have surfaced in the literature in recent years. This research offers a comparison analysis designed to assess the effectiveness of several change detection techniques. The techniques that are examined range from pixel-based methods like image ratio, image differencing, log ratio (LR), and means ratio (MR) to sophisticated fusion methods that combine many pictures to get an all-inclusive depiction of change [2, 3]. Through a methodical comparison of different approaches, we want to clarify the advantages, disadvantages, and applicability of each. There are other change detection methods like discrete wavelet transform (DWT) and stationary wavelet transform (SWT), which transform the

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pixel values to wavelets and then give change map by fusing the different components of images together [4–13]. Robust and effective change detection techniques are becoming more and more necessary as Earth observation technology develops and varies. By shedding light on the performance traits of current approaches and pointing out opportunities for improvement and innovation, this study hopes to add to the larger conversation on Earth surface monitoring. The fuzzy c-means clustering technique has been used to generate a change map by separating the changed pixels from the unchanged pixels [14–16].

The practice of detecting changes in an object's or phenomenon's condition by observing it at various times is known as change detection. This entails comparing photos taken at various dates to identify changes in the region of interest when it comes to high-resolution photographs. Detailed information is provided by high-resolution photography, which enables the detection of even minute changes. Change detection is critical to many fields, including environmental research, urban planning, remote sensing, and disaster management. This article compares several change detection techniques in an effort to assess each one's effectiveness and applicability.

METHODOLOGY

In the pixel-based change detection methods shown in Figure 1, two registered multitemporal images which are taken at different times are fed to a change detection method. The change detection method can be a direct differencing-based method in which corresponding pixels of one image are subtracted from other to generate a new image. The other technique is image ratioing in which ratio of the corresponding pixels of the two images is taken to generate the difference image. The ratioing can be log ratio and means ratio.

The other type of change detection method is wavelet transform based, in which the images are transformed into wavelets by using discrete wavelet transform (DWT) or stationary wavelet transform (SWT) method. Then the wavelet transform method decomposes the original image into approximation and detail coefficients at various scales as shown in Figure 2. The decomposed images are then fused together using fusion rules to generate a fused image, which contains properties of both the input images. In this way, the features can be enhanced to obtain more details from the different images. The fused image is then clustered into changed and unchanged pixels by using the image clustering method. The output of image clustering method is changing map.

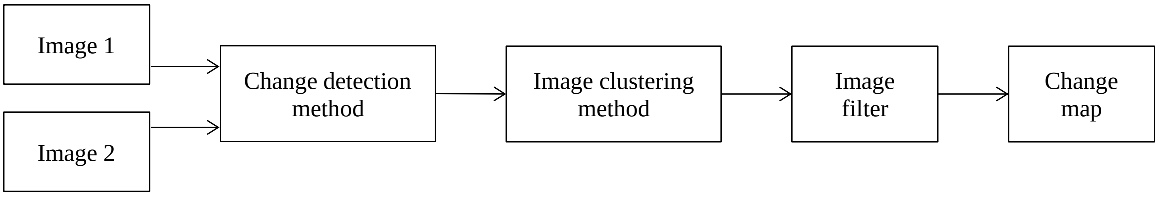

Figure 1. Pixel-based change detection method.

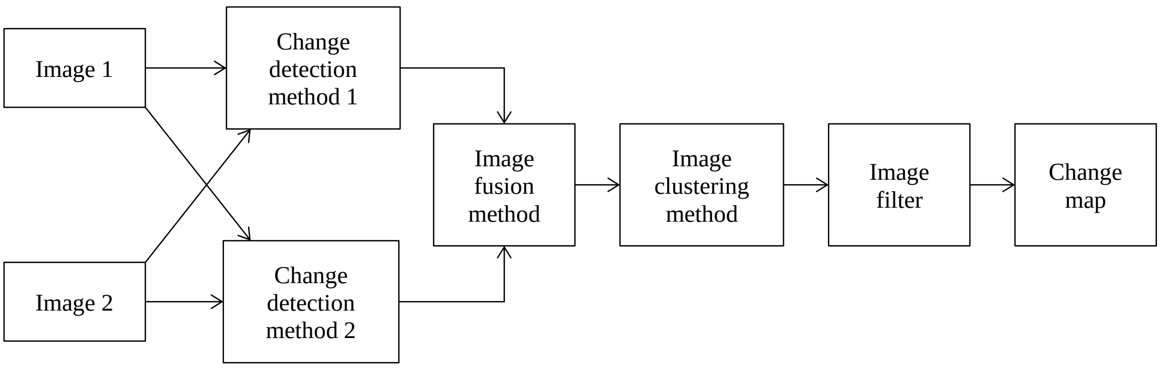

Figure 2. Wavelet transforms–based change detection method.

The comparison research focuses on a number of widely used techniques for high-resolution picture change detection. These techniques can be broadly divided into three categories: object based, pixel based, and machine learning based. The methodology section describes how these methods are assessed according to standards, including accuracy, computing efficiency, and scenario applicability.

Elements of Methods for Detecting Change

Pixel-based Techniques

- *Image differencing:* This process involves deducting an image's pixel values from another.
- Image ratioing is the process of dividing an image's pixel values by its matching image's pixel values.
- *Change vector analysis (CVA):* Looks at the difference matrices in multi-temporal images to find changes using vector research.

Methods Based on Objects

- *Segmentation:* Separates the picture into sections or items that have meaning.
- *Classification:* Labels segments according to their attributes.
- *Post-classification comparison:* Identifies variations by comparing categorized photos at different points in time.

Methods Using Machine Learning

- *Supervised learning:* Supervised learning makes use of labeled training data to identify and learn from changes.
- *Unsupervised learning:* It detects modifications using built-in data structures; does not require labeled data.
- *Deep learning:* This approach makes use of neural networks to automatically identify features and accurately identify changes.

Utilizations

- *City planning:* keeping an eye on land use changes and urban sprawl. monitoring the development of infrastructure.

Monitoring the Environment

- Assessment of reforestation and deforestation. Changes in wetlands and coastal areas.
- *Management of disasters:* after-natural disaster damage assessment. Tracking the efforts to rebuild and recover.

DATASET AND PARAMETERS

The image dataset of the city of Bern, Switzerland has been used in this paper. The images were captured during the time the area was affected by the flood. One image was taken in the month of April 1999 and the other image was taken in the month of May 1999. The image captured in April is shown as Figure 3(a) and image captured in May 1999 is shown in Figure 3(b). The ground truth used to check the performance of different algorithms is shown in Figure 3(c). The image size of 329 × 329 has been used in this paper.

RESULTS AND DISCUSSION

The change maps generated by different change detection methods are given in Figure 4. It can be seen from the output of log ratio that most of the true positive has been recovered but it is not able to recover some of the areas that have changed. In the output of mean ratio method, there is large number of false alarms, which shows that the algorithm has shown many areas as changed region while there is no change in actual change map for these areas.

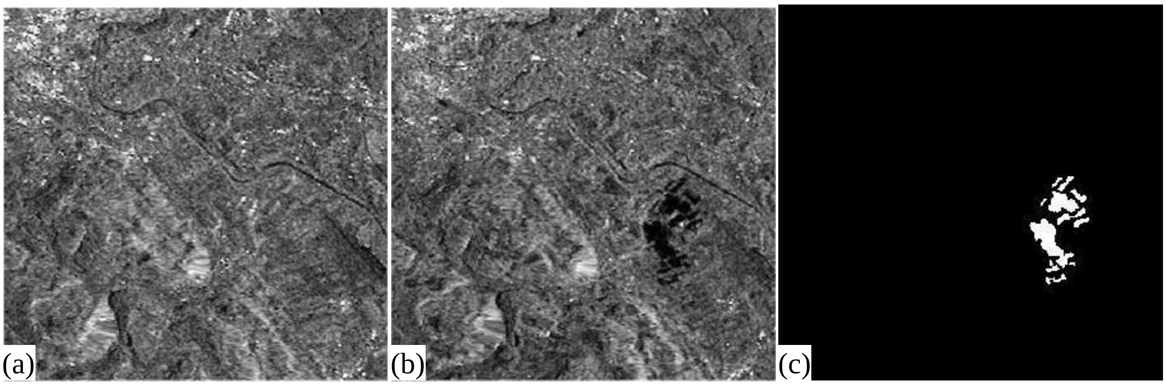

Figure 3. Multi-temporal images of Bern city (a) April 1999, (b) May 1999, (c) Ground truth [5].

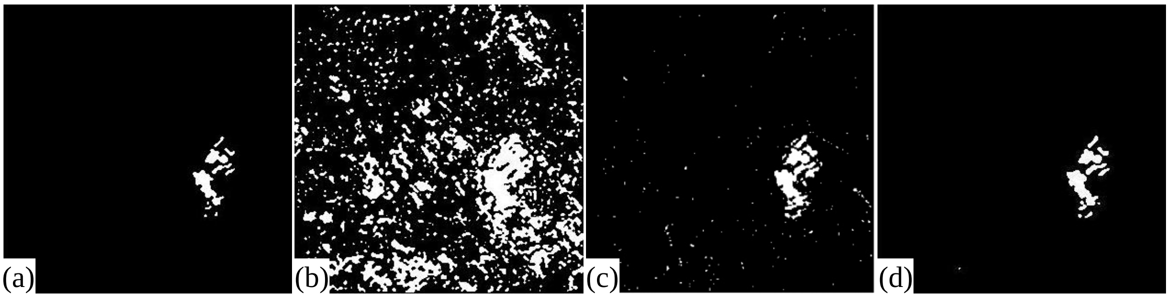

Figure 4. Change map generated by different change detection algorithms: (a) log ratio (LR), (b) means ratio (MR), (c) discrete wavelet transform (DWT), and (d) stationary wavelet transform (SWT).

In the DWT method, most of the changed areas have been recovered but there is some noise visible in the background, which shows false alarms given by the changed detection algorithm. As far as the SWT is concerned, the algorithm has given the best output as compared to other change detection algorithms shown here. The algorithm has been able to recover most of the changed pixels and the false alarms generated are also less.

DISCUSSION

Every method has benefits and drawbacks, as the comparative analysis shows. Pixel-based techniques are straightforward and effective in terms of computation, but they may be noisy and necessitate cautious thresholding. Although object-based approaches are computationally demanding, they offer more relevant change information by taking objects into consideration instead of individual pixels. While deep learning in particular offers high automation and accuracy, machine learning–based techniques necessitate substantial computer resources and vast datasets. The particular application, the resources at hand, and the level of accuracy required all influence the approach selected.

CONCLUSION

In this paper, performance of various change detection methods has been compared by applying multitemporal image dataset of the city of Bern, Switzerland captured during the time the area was affect by flood. Both the images were fed to log ratio, mean ratio, SWT, and DWT methods. The qualitative analysis has been performed to check the performance of various algorithms compared in this paper. From the qualitative analysis, it is clear that SWT offers good results in terms of true positive and true negative generation. SWT is able to recover most of the changed pixels and has shown least number of false alarms as can be seen from the output of change map of all the algorithms. From these qualitative results, we can say that SWT is the appropriate method as compared to rest of the methods applied here for the given dataset. Change detection is an important task with a broad range of applications in high-resolution images. This comparison analysis demonstrates that there is no one approach that is always better; each has advantages and is appropriate in certain situations. Pixel-based techniques might be adequate for rapid, large-scale evaluations. Object-based and machine learning–based techniques are better for more precise and in-depth change detection. Future work should concentrate on combining these techniques to take advantage of their individual advantages and creating more effective algorithms to deal with the growing amount and complexity of high-resolution pictures.

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