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Change Detection in Synthetic Aperture Radar Images

Sangeetha R Revathy

Assistant Professor, Computer Science Department, Mount Zion Engineering College

Abstract: ***In this paper, we introduce a new approach for detecting the changes in SAR images that is taken from same geographical areas but at different periods of time. In this particular change detecting strategy, firstly, the ratio operator is applied to the SAR images to get the difference image. Here , log ratio and gauss log ratio operator is used to get the difference image. Then the difference image is fused by DWT.Noise in the fused image is removed by NSCT, which will remove the noise while preserving the information, especially the edge information. This denoised image is converted to compressed vectors by compressed projection thus reducing the dimension .Finally the changed and unchanged region is detected by clustering using fuzzy c mean (FCM) clustering with a novel Markov Random Field (MRF) energy function which aids in modifying the membership of each pixel and thus improving the accuracy in change detection.***

Keywords: Discrete Wavelet Transform (DWT), Non Subsampled Contourlet Transform (NSCT),Fuzzy C Mean(FCM),Markov Random Field (MRF)

1. Introduction

Change detection is the process that helps in detecting the changes happening to two SAR images taken from same geographical area but at different periods of time. This change detection techniques mainly involves two steps. Firstly ,generation of difference image to classify it into changed and unchanged classes. The difference image is obtained by ratio operators. They are robust to radiometric and callibration errors. The ratio operators are robust to radiometric and callibration errors. Secondly, this difference image is analysed and classified into changed and unchanged region. Some of the ratio operators are mean ratio operator, log ratio operator,gauss log ratio operator etc.The changed and unchanged regions are obtained by clustering and classification methods like k mean clustering,fuzzy clustering etc.

There are different techniques for detecting changes in SAR images. Changes in SAR images can be detected by a detail preserving scale driven approach [1] .Here multiresolution decomposition is performed on the SAR images. Then the adaptive scales are identified followed by scale driven fusion. Even though the method is useful for information preserving, there are chances of false alarms, which is the problem that occurs when the unchanged region is detected as changed region approach .In this method the difference image is obtained by Neighbourhood Ratio operator(NR) and the changed and unchanged regions are obtained by Killer Illingworth thresholding.Since this thresholding technique involve selecting more than one threshold value , this method is epensive.Even though it removes the multiplicative noise , there are chances of false positives ie the unchanged region may be detected as changed one.

There are different fuzzy clustering techniques which is used to cluster the changed and the unchanged region. Normal fuzzy clustering technique [3] is used to obtain the change map from which we can identify the changed and unchanged region. It has robust characteristic and preserves most of the information that is contained in the original image. Since it doesnot contain spatial information,FCM is very sensitive to noise.Fast Generalised FCM(FGFCM) [4] includes the spatial information . It is less sensitive to noise due to the inclusion of partial information.Fuzzy Local Information C Mean clustering [5] uses a local fuzzy similarity measurement. This clustering technique is less sensitive to noise and all the required information are preserved. In Reformulated Fuzzy Local Information C Mean clustering [3] is used to enhance the information in the changed region by including the spatial information ,by accomplishing the objective function with a new fuzzy factor. This hence modifies the objective function and reduce the speckle noise. In Spatial Constrained Fuzzy C Mean [6] method will modify the cluster center by adding term to the objective function. Among the fuzzy clustering techniques Markov Random Field FCM is the best method because it improves the classification by modifying the membership function. All the calculations in each step is found to be less which make this method less time complex as well as the same time more accurate. The edge information are well preserved.

2. Proposed Work

The technique which is used here to detect the changes in SAR images is to first get 2 SAR images which is taken from same geographical areas but at different time periods. Change detection mainly includes two steps ie,the generation of the difference image and analysis of the difference image.

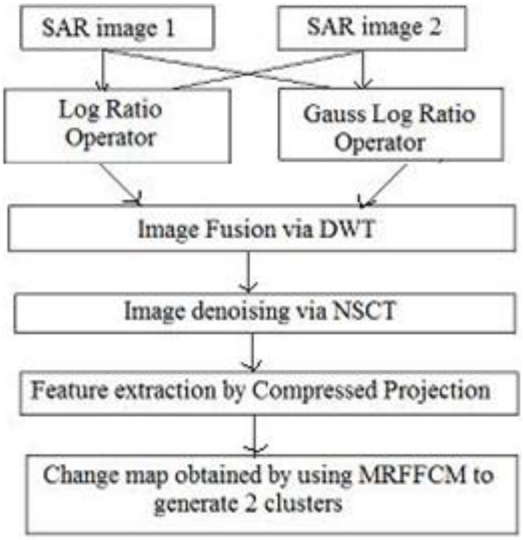

Figure 1: Overall architecture of the proposed work

As given in Figure 1,the two SAR images are given as the input to the change detection system. The difference image is obtained by log ratio and gauss log ratio operator.These difference images are fused by DWT.The noise present in the fused image is removed by denoising method called NSCT(Non Subampled Contourlet Transform).Compressed projection is used to extract the features. Change map is obtained by Markov Random Field Fuzzy C Mean clustering ,which helps to identify the changed and the unchanged region.Each step is explained briefly in the following sections.

A. Difference Image obtained by Log Ratio and Gauss Log Ratio operator

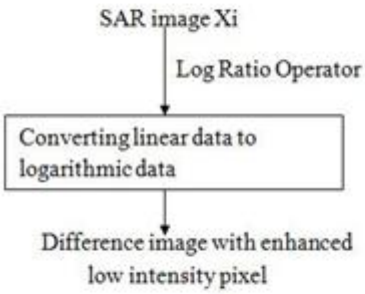

Figure 2: Log Ratio Operation

Ratio operators are used to get the difference image.These ratio operators are robust to radiometric and calibration errors.Log Ratio operator[7] is one such operator in which multiplicative noise is transformed to additive noise ,since the linear data is converted to logarithmic data.There are operators like Mean Ratio operator,but here the difference image obtained is fuzzy.It is very difficult to separate changed and unchanged region. The change obtained may not be the real change trend because it modify the local mean value and the changes in texture structure cannot be identified.

The log ratio operator helps to enhance the intensity pixels of the changed region while weakening the high intensity pixel as indicated in figure 2.Thus Gaussian filtering added to the log ratio operation helps to get a highly contrast difference image which is explained in [8].

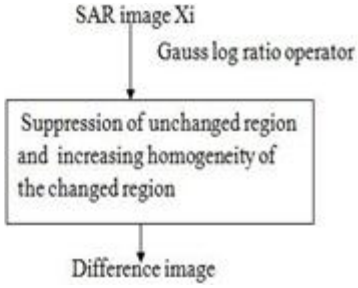

Figure 3: Gauss Log Ratio Operation

The rotationally symmetric matrix used for Gaussian filtering is as follows:

$$G = \begin{bmatrix} 0.00113 & 0.0838 & 0.0113 \\ 0.0838 & 0.6193 & 0.0838 \\ 0.0113 & 0.0838 & 0.0113 \end{bmatrix}$$

Gauss-log ratio operator explained in the paper “Unsupervised Change Detection in SAR. Image Based on Gauss-Log Ratio Image Fusion and Compressed Projection”[8], which considers the relationship between the intensities of local patches of multitemporal images. SAR images are inherently degraded by multiplicative speckle. The main function of Gauss log ratio operation is shown in figure 3. Hence, the unchanged portions in multitemporal SAR images acquired at the same geographical area also have a little difference, which usually results in many fractional regions not belonging to the real change portions in the detection result, whereas the changed portions usually lack the integrity during the subsequent clustering or classification because of the speckle. So, we use the rotationally symmetric Gaussian low-pass filter to reduce the fractional regions and make the changed portions more homogeneous.

B. Image Fusion via DWT

In order to obtain a better difference image, we need to fuse the image to get the better difference image. Image fusion is the process of fusing two source images to collect the relevant information to get fused image which contain more information than that of the source images.

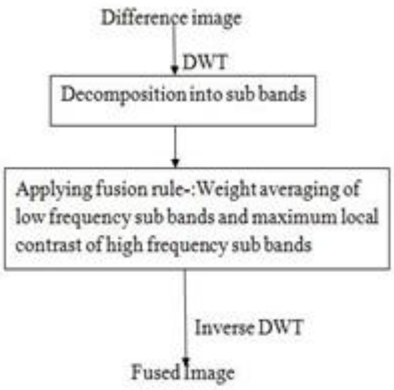

Figure 4: Image fusion via DWT

This technique is better in such a way that there is a greater contrast between the changed and the unchanged region.The accuracy of the subsequent clustering and classification can be improved by the homogeneity of the changed region. Discrete Wavelet Transform is used because the correlation between the adjacent pixels are overcome. It also has an advantage that the local variation of the original images are rreflected.Difference map is improved by the choice of the fusion rule. The fusion rule used here is that, for the low frequency band, weight averaging is obtained and for the high frequency band maximum local contrast is selected.Maimum local contrast which is obtained by mathematical calculation given in [8]and is clear from figure 4.This helps to enhance the radiation intensity of the changed region while comparing it with the unchanged region. Inverse DWT will give the fused image.

C. Image Denoising via NSCT

It is one of the latest techniques for removing the noise that is present in the difference image which is obtained even after the image fusion. It has some of the characteristics like multiresolution, shift invariant etc.It mainly includes two step.

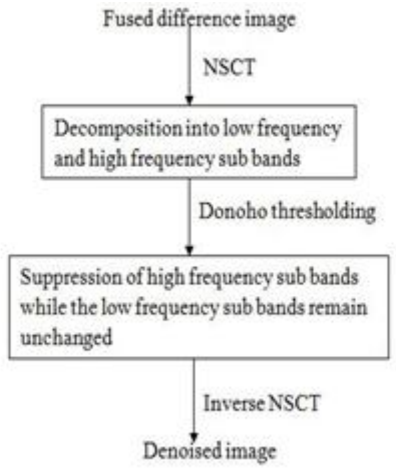

Figure 5: Image denoising via NSCT

Firstly, the fused image is decomposed into low frequency sub bands and high frequency subbands in different direction and different scales. Secondly the coefficient of low frequency sub bands remains unchanged, while the coefficient of high frequency directional sub bands is suppressed by Donoho Threshold which is explained in [8] and is explained in figure 5.

D. Feature Extraction via Compressed Projection

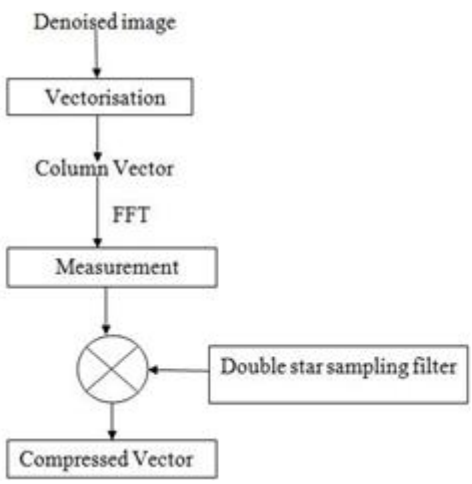

Figure 6: Feature extraction by compressed projection

Compressed projection has many application in signal processing [8]-[10].It is also called random projection. When the signal is projected to the basis function ,it will retain mot of the required information. Even though some information may be lost due to the projection subsequent clustering, that information are not the relevant information for the subsequent clustering and classification. That is, the number of compressed vectors obtained may be small, but this is enough for preserving all the required information for the clustering and classification which occur subsequently. One of the great advantage of the compressed projection is dimension reductionality.This will reduce the amount of data that is required for the further analysis. One of the root cause for the emergence of theory of compressed sensing (CS) [11]-[13] is the information preserving nature and its dimensionality reduction.

Firstly the column vector is obtained by the vectorisation process. The column vector is undergoing a process of FFT and thus obtain a measurement matrix.Then a double star shape sampling filter is applied to obtain compressed vector as explained in figure 6.

E. Change Map obtained by MRFFCM

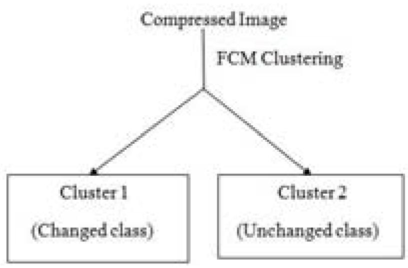

Figure 7: FCM clustering

Fuzzy C Mean algorithm provides a better result for the change detection but there are some improvements that is given to the fuzzy clustering algorithm. There are different fuzzy clustering techniques which is used to cluster the changed and the unchanged region. Normal fuzzy clustering technique [3] is used to obtain the change map from which we can identify the changed and unchanged region.It has robust characteristic and preserves most of the information that is contained in the original image. Since it doesn't contain spatial information,FCM is very sensitive to noise. Figure 7 shows the function of FCM briefly. Fast Generalized FCM(FGFCM) [4] includes the spatial information. It is less sensitive to noise due to the inclusion of partial information. Fuzzy Local Information C Mean clustering [5] uses a local fuzzy similarity measurement. This clustering technique is less sensitive to noise and all the required information are preserved. In Reformulated Fuzzy Local Information C Mean clustering [3] is used to enhance the information in the changed region by including the spatial information, by accomplishing the objective function with a new fuzzy factor. This hence modifies the objective function and reduce the speckle noise. In Spatio Constrained Fuzzy C Mean [6] method will modify the cluster center by adding term to the objective function. Among the fuzzy clustering techniques Markov Random Field FCM is the best method because it improves the classification by modifying the membership function. All the calculations in each step is found to be less which make this method less time complex as well as the same time more accurate. The edge information are well preserved.

FCM is modified by Markov Random Field Fuzzy C Mean(MRFFCM) clustering by modifying the membership of each pixel. The main steps of MRFFCM is shown in figure 8.MRF energy function includes the information about the relationship among the neighbouring pixels.It concentrates on the modification of the membership function which helps to reduce the speckle noise and increase the accuracy of clustering. This technique will include the spatial context which is obtained from the information of the neighbouring pixels novel energy function is also added to the MRF to increase the accuracy of the process. Before updating the membership function ,we need to find the point wise prior probability from Gibbs expression which is explained in [14].Spatial context is included by adding MRF to normal FCM.

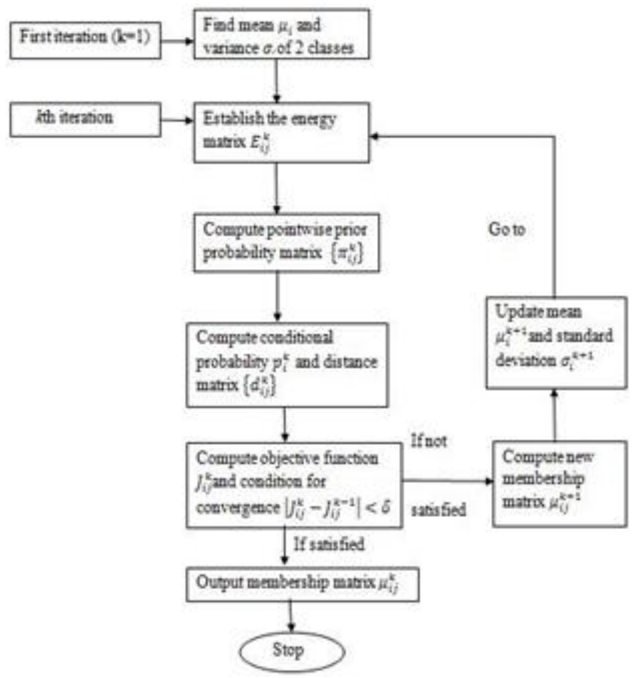

Figure 8: Adding MRF into FCM

Following are the main step in MRFFCM

1) Mean and standard deviation of the two classes Are obtained in the first iteration (k=1) by K & I method [15].Generates the initial membership matrix and by using a threshold (0.5) ,same kind number matrix is also generated. Number of neighbourhood pixels belonging to the central pixels are the elements of the matrix.

2) Energy matrix is established in the kth iteration.It is the important factor which includes the spatial context .More detail description of the energy function is explained in [16].Energy matrix is represented in the form

$$E_{ij}^k$$

3) Point wise prior probability is computed from the Gibbs expression [14].Point wise prior probability matrix is obtained.

$$\pi_{i,j}^k = \frac{\exp(-E_{i,j}^k)}{\exp\left(-E_{u,j}^k\right) + \exp(-E_{c,j}^k)}$$

4) Conditional probability is computed and distance matrix is generated. Conditional probability can be calculated as-:

$$p_i^k(y_j(\mu_i^k, \sigma_i^k)) = \frac{1}{\sigma_i^k\sqrt{2\pi}} exp\left[-\frac{(y_j - \mu_i^k)^2}{2(\sigma_i^k)^2}\right]$$

Distance matrix can be calculated as-:

$$d_{ij}^k = -ln\left[p_i^k(y_j|\mu_i^k, \sigma_i^k)\right]$$

5) Objective function is calculated and the process stops and output the membership matrix when a convergence is reached, otherwise go to step 6.Objective function is calculated as follows-:

$$J_{ij}^k = \sum_{i=u,c} \sum_{j \in I_X} (u_{ij}^k)^2 (d_{ij}^k)^2$$

The convergence criterion is as follows:

$$|J_{ij}^k = J_{ij}^{k-1}| \leq \delta$$

6) For the next iteration process new membership is computed and thus create the membership matrix which is given by-:

$$u_{ij}^{k+1} = \frac{\pi_{ij}^k exp(-d_{ij}^k)}{\pi_{uj}^k \exp(-d_{uj}^k) + \pi_{cj}^k exp(-d_{cj}^k)}$$

7) Update the mean value-:

$$\mu_i^{k+1} = \frac{\sum_{j \in I_X}(u_{ij}^k y_j)}{\sum_{j \in I_{XX}}(u_{ij}^k)}$$

and update the variance value-:

$$\sigma_i^{k+1} = \sqrt{\frac{\sum_{j \in I_X}[u_{ij}^k (y_j - u_i^{k+1})^2]}{\sum_{j \in I_X}(u_{ij}^k)}}$$

Increment the counter k-k+1and go to step 2

3. Experimental Results

A. Dataset

RADAR SAR sensor provides the Ottawa dataset (290x360).It is the section of two SAR images in the city Ottawa. The Defence Research and Development, Canada, Ottawa provides the dataset.The two images which are collected on may and august 1997 is contained in this particular dataset. They are acquired from the area where the flood has affected at least one time. By using the prior information and interpreting the photo, the truth map is obtained.

B. Evaluation Criteria

We obtain the final change detection map after the application of the proposed method, then we apply some of the evaluation criterion to compare the performance and accuracy of different methods.

The number of entire pixels N is calculated from the available ground truth. The actual number of the pixels present in the changed and unchanged map is calculated according to the change detection map ie *Nu* and *Nc* respectively. The reference map and the change detection map which is obtained by certain approach is compared pixel by pixel. While we do this we are able to get the values of false positive which can be defined as the number of pixels in the unchanged class which are detected falsely as changed class pixels. Similarly there is a chance of obtaining false negative which can be defined as the the number of pixels in the changed class which are detected falsely as unchanged class pixels ie *FP* and *FN* respectively. The correctly detected changed and unchanged pixels *TP* and *TN* can be calculated as-:

$$TP=Nc-FN$$

$$TN=Nu-FP$$

For the further evaluation, percentage correct classification (PCC) is used which can be defined as-:

$$PCC = \frac{TP+TN}{N}$$

It will provide correct result rate.

Since the difference image is regarded as image segmentation method Kappa Coefficient(*KC*) is considered as one of the better evaluation criterian. If the value of *KC* is higher than the better image segmentation is obtained. Kappa Coefficient can be calculated as follows-:

$$KC = \frac{PCC-PRE}{1-PRE}$$

where,

$$PRE = \frac{(TP+FP).N_c + (FN+TN).N_u}{N^2}$$

More information is included in Kappa Coefficient than that of percentage correct classification because KC depends on TP and *TN* values while the *KC* depends on its sum.

C. Performance Evaluation

There are different methods that are used to detect the changes in the SAR images. While evaluating the performance of different method with certain criterian, we are able to identify better change detection method. Following I the table showing different methods and the value obtained by attaining certain criterions.

Table 1: Comparison with Evaluation Criterian

	Method	FP	FN	PCC	KC
Ottawa dataset	KI	1366	760	97.95%	0.72
	FCM	190	349	99.41%	0.74
	FLICM	723	84	99.11%	0.80
	RFLICM	724	61	99.13%	0.81
	MRFFCM	364	47	99.95 %	0.92

While comparing different methods with the evaluation criteria ,it is clear that the *PCC*(Percentage Correct Classification) and *KC* (Kappa Coefficient) are high for MRFFCM.From the table the KI (Killer Illingworth) thresholding technique have the *PCC* value of 97.95% and *KC* have the value of 0.72.The value of *KC* is always represented in the range of 0-1.FCM(Fuzzy C Mean) clustering technique have its *PCC* value of 99.41% and its *KC* value is 0.74.

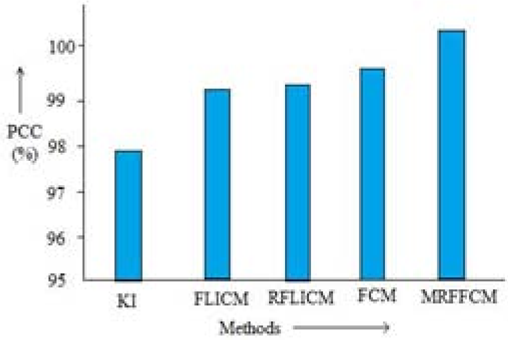

Figure 9: Bar chart showing the value of PCC for different methods

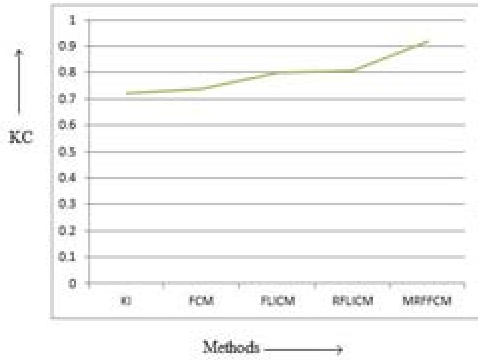

Figure 10: Pie graph showing KC value for different methods

Fuzzy Local Information C Mean (FLICM) clustering technique have its *PCC* value of 99.11 from the figure 9 and its *KCC* value is 0.80.One of the improved form of FLICM clustering,ie Reformulated Fuzzy Local Information C Mean (RFLICM) has its *PCC* value of 99.13% and has the KC value of 0.81.Markov Random Field Fuzzy C Mean clustering is on method which is having greater value of *KC* and *PCC*. Since it have the highest value of KC,it has a better segmentation quality which can be infers from the figure 10. From the comparison which is obtained

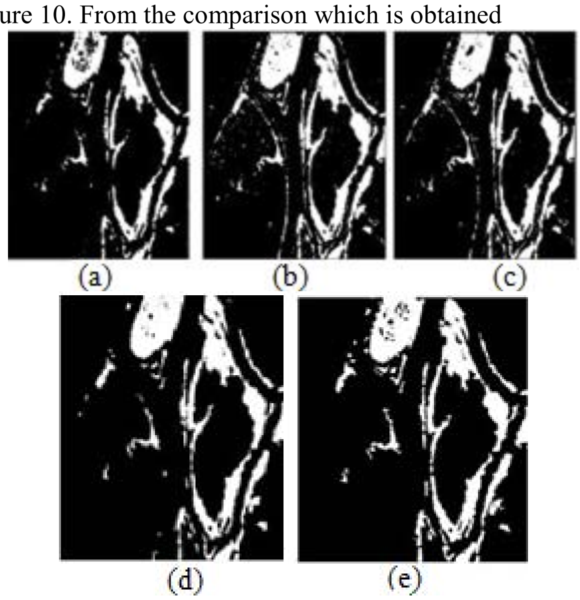

Figure 3: Evaluation of performance done on Ottawa dataset (a) FCM technique (b) FLICM (c) RFLICM (d) KI (e) MRFFCM

by applying various criteria.From the evaluation it is clear that MRFFCM is the better method for the change detection in SAR images which are taken from same geographical area but at different time intervals. More accuracy is obtained by the removal of speckle noise and preserving the information of the edges.

4. Conclusion

In this method a change detection that is done by the log ratio and gauss log ratio based image fusion, compressed projection and subsequent clustering is obtained by MRFFCM.This method have many applications like video survilliances,remote sensing, medical diagnosis etc.This method first obtains the difference image by log ratio and gauss log ratio operator. This difference image is hen analysed.The difference images are fused by DWT based image fusion.The noise in the fused image is removed by NSCT technique. Then the compressed projection is applied for the subsequent clustering. Finally the change map is obtained by MRFFCM.This method removes the speckle noise by including the spatial information.Since all the steps in its procedure are simple, hence it is less time consuming. This method enhance the edge information which is the major problem of other technique.

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