CHANGE MECHANISM ANALYSIS AND INTEGRATION CHANGE DETECTION METHOD ON SAR IMAGES

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ABSTRACT:

Synthetic aperture radar (SAR) image change detection is a very complex problem like SAR imaging mechanism. Every change detection method has its advantage and disadvantage, and there are no optimal change detection approaches. If general means is directly applied to SAR image change detection, the results are usual no ideal. Sometimes, for a pair of multitemporal SAR images, different detection methods can obtain different detected results; what's more, the results are contrary. In order to improve SAR image change detection precision, this paper detailedly studies SAR image change mechanism, makes classifications to SAR image change types, and proposes a novel all texture features fusion change detection method and an integration SAR image change detection algorithm. Finally, the airborne SAR image data of Canadian Convair-580 C/X-SAR tests the methods, and experimental results indicate that the presented methods are feasible.

1. INTRODUCTION

SAR is an active microwave coherent imaging radar, so it can acquire remote sensing data under all weather and all time, which can made up for the shortage of optics and infrared remote sensing. At the same time, SAR can monitor and survey large ground surface from long range, and has some penetrability. Therefore, it has been widely applied in civil and military fields (Guo, 2000; Oliver, 1998). SAR image change detection technique is to acquire ground object change information of the same area SAR images in different date and to further realize the qualitative or quantitative analyses of an object. It is a technology that aims at SAR image feature to found data analysis method and is used to recognize the change of state for an object or phenomena. With the development of SAR image technology, multi-platform, multi-band, multi-polarization SAR image resources provide the advantage for change detection. At present, SAR image change detection has been become the issue of remote sensing research and has widely potential applications. In civil field, it can be utilized in disaster surveillance and assessment for the earthquake, flood, mud and rock flow of natural disaster and the forest fire; it can be used to monitor and survey ocean resource, ocean environment and seaport; it can be used for monitoring and assessment to environmental change and pollution; it can obtain the change information for land utilization, forest and vegetation change, marsh change, city extension, terrain change; it can monitor and evaluate crop growth state; it can update the basic geographic database (Bruzzone, 1997; Merril, 1998; Zhang, 2005; Paolo, 2007; Quegan, 2000). In military filed, SAR can realize continuous reconnaissance for battlefield area or key monitoring targets; it can be used for target battle damage assessment, battlefield information dynamic perception, monitoring military target and distribution of troops (Fu, 2003; Huang, 2007). In addition, SAR has some penetration abilities, so it can penetrate some vegetation and man-made camouflage, and can detect the masked military installations and equipments. Because the radar reflection features relate with the dielectric constant of target surface material, SAR data can make quantitative analysis for target surface material and reach the aim of judging the trueness and falseness (http: //jczs.news.sina.com.cn/p/2006-11-05/0735409951.html). When the target can't be detected and recognized by visible light and infrared remote sensing, SAR can detect it very easily because general targets are rather sensitive to microwave remote sensing. Therefore, multi-temporal change detection can provide abundant remote sensing information for target recognization.

In the late ten years, some literates have made a great amount of studies about the applications of SAR image change detection, presented a great number of SAR image change detection methods (Chen, 2007; Castellana, 2007; Francesca, 2005; Lorenzo, 2007; Eric, 1993; Chen, 2004; Jiang, 2006; Inglada, 2007; Gabriele, 2007), and obtained some achievement. But the field is still a focus that many experts pay attention, for the potential applications of SAR image change detection are very great. Multitemporal remote sensing image change detection methods may be classified into two big types (Lu, 2004): comparison after classification and direct comparison. The direct comparison method is relative simplicity, but it especially fit for SAR image change detection analysis when the carriers have the repeated and steady orbit, and the calibration performance is good (Eric, 1993). It main includes image grey difference method, image grey ratio method, image texture feature difference method, correlation coefficient method, image regression method and canonical correlation method. The comparison after classification is to independently classify for each image, then to identify the changed area according to the difference of the corresponding pixels. It includes supervised and unsupervised classifications. This way may overcome the inconvenience that the sensor and resolution of the multitemporal image bring differences. It does not need data normalization, for the two images are classified independently. But the main shortcoming is that the classification errors can produce combination influence, namely, the change map precision that the two independent classifications brings is approximate the product of each precision.

Each SAR image change detection method has its advantage and disadvantage. Even the multitemporal SAR image comes from the same area, but if the applied approach is different, the detected results are different, and sometimes they are contrary. This is reason that every method tests the target change from different aspects. For example, the image grey difference algorithm examines whether or not the target changes from image colour shade; the image texture feature difference method considers it from the grey space relation between the neighbour pixels; the correlation coefficient approach detects the change from the correlativity of targets. Forest and vegetation change with different seasons, and the corresponding SAR images are different. Using the image difference method and the correlation coefficient method, the detected results are change, but the result of the texture difference method is no change. In practical application, no one of methods is optimal and there is not a uniform standard. Hence, we should choose the befitting change detection approach in terms of the practical applied demand.

This paper considers whether or not the object changes from the SAR imaging principle and the object scattering mechanism, studies SAR image change mechanism deep, and proposes SAR image change classification type. At the same time, the paper discusses the earth surface parameters which cause SAR image change and combines the advantage and disadvantage of single change detection method. Then it proposes a novel integration SAR image change detection algorithm, which reduces the errors of change detection. Finally, the real SAR images are used to test the method, and the experimental results show that the proposed approach is effective.

In section 2 the SAR image change mechanism is studied deep. Then section 3 presents the classification of SAR image change type in terms of SAR image change mechanism. In section 4 the proposed new SAR image change detection algorithm is described, which includes all texture feature fusion change detection algorithm and an integration SAR image change detection algorithm and section 5 is experimental results and analysis. Finally the presented work is summarized and concluded in section 6.

2. SAR IMAGE CHANGE MECHANISM

SAR image change detection is also an identifying way for ground object state difference like optical remote sensing image. Remote sensing image change detection usually includes four item contents: (1) detect the change which has been taken place; (2) identify the change quality; (3) judge the range of the change area; (4) assess the change space mode. In general, the narrow change detection concept points to the pre-two item contents, which are not only the basic aim that change detection reaches but also the basic problem that change detection need to be solved.

Considering the change from philosophy, the changes of matter divide into two types: quantitative change and qualitative change. The quantitative change refers to the change of quantitative accumulation and subduction of one sort interior in classification system; namely, the sort does not take place change, such as crops growing change, forest or vegetated seasonal change and the drift of the polar ice. The qualitative change refers to the change of qualitative between two different sorts in classification system; namely, the sort takes place change. One sort becomes into another sort, such as a building turns into grassland or grassland turns into a building. Both quantitative change and qualitative change causes SAR image change.

SAR is high resolution 2-D imaging radar. The imaging essential is a mapping from ground object space to scene space through the corresponding function and the aim is to obtain 2-D distribution of target area backscattering coefficient. Therefore, SAR image is the expression of ground object backscattering echo intensity. The target backscattering coefficient is decided by radar system parameters and ground surface parameters. The formula is given by

$$\sigma^0 = f(\lambda, \theta, P, \varphi, \varepsilon, \Gamma_1, \Gamma_2, V) \tag{1}$$

Where, λ is wavelength, θ is incident angle, P polarization mode, φ is azimuth angle, ε is complex dielectric constant, Γ_1 is surface roughness, Γ_2 is sub- surface roughness, V is bulk scattering coefficient of inhomogeneous medium.

The image sequence set of SAR change detection generally demands to satisfy the conditions: the same sensor, the same ascend orbit (or descent orbit), the same or near incident angle, the same or near azimuth angle. It supposes that the radar system parameters don't change and the change of SAR image is mainly brought by ground surface parameters. As shows that the scattering echo intensity of ground objects is decided by the dielectric constant, the ground surface roughness (or surface physical structure of ground object) and the coherence of echo. Some ground objects like forest have bulk scattering except for surface scattering. The reason of SAR image change that ground environmental parameters cause is shown in Fig.1.

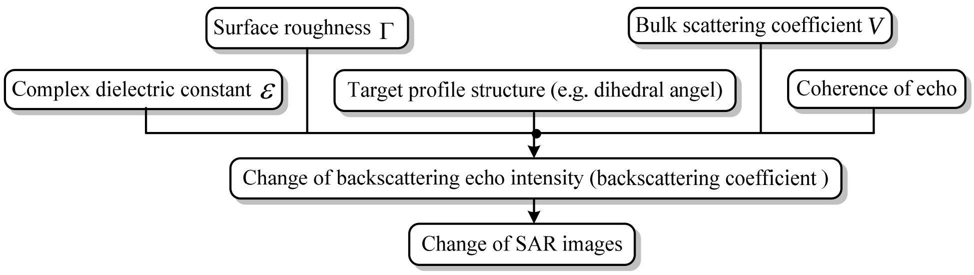


Figure 1 SAR image change factors from ground parameters

2.1 Surface roughness

Surface roughness is a unit of measurement that describes ground surface geometry size. Here the surface roughness refers to the surface rough degree in one radar resolution cell, such as mineral, gravel, the size of vegetable branches and leaves, the height difference of small terrain, rather than the big fluctuant terrain cell like mountain, hill, flat and tableland. Such roughness generally divides into three instances: (1) smooth surface; (2) light roughness and middle rough surface; (3) great rough surface. They are shown by Fig.2 (Guo, 2000).

Smooth surface produces mirror reflection and the reflected energy almost gathers in a small solid angle range with the

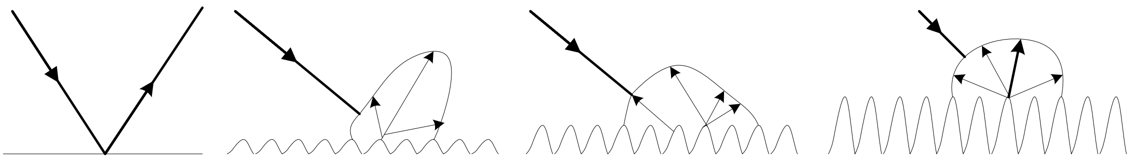


Figure 2 The reflection and scattering of different rough surfaces (Guo, 2000)

reflected line as a centre. In general, hardly any echo signal returns and the SAR image is dark. Only is when radar wave beam upright the surface of a ground object, radar can receive very strong echo. Still water, airfield runway, tiled road and flat roof are the smooth surface objects. Light and middle rough surfaces reflect energy at every direction. Radar receives letter echo signal and SAR image is grey. Great rough surface can evenly scatter energy forward all directions. Radar can receive strong reflection echo and SAR image is bright. Such as grassland, forest, bare soil, they generally belong to rough surface, and forest is typical anisotropic scatterer.

The rough degree of surface is relative to radar incidence frequency. If the frequency changes, surface roughness of ground object will change with it. Surface roughness is usually decided with Rayleigh criterion. Therefore, in SAR image change detection, it demands the same sensor, namely, the frequency of incident wave does not change. The roughness of ground objects changes and the backscattering intensity also changes following it, which leads to final SAR image change.

2.2 Complex dielectric constant

Complex dielectric constant is one of physical characteristics of ground objects, which has important influence to radar echo. Large numbers of experimental results show that if dielectric constant is bigger, reflection echo is stronger and the penetration ability is less; whereas, echo intensity is less, the penetration ability is bigger, under other factors same. Being relative to the liquid water content of the unit volume, complex dielectric constant is linear variation. When liquid water content is more, reflection energy is larger and SAR image is brighter. For different seasonal vegetable, liquid water content is different and the acquired SAR image has obvious change. If tanks are hidden in forest or concealed in desert, the local dielectric constants will increase and the corresponding area will become bright in SAR image. Therefore, complex dielectric constant is one of important factors that cause SAR change.

2.3 Target outline physical structure

When target outline physical structure takes place change, it leads to scattering echo change, especially corner reflector effect. Corner reflectors include dihedral corner reflector which is formed by two mutual upright surfaces, trihedral corner reflector which is formed by three mutual upright surfaces, rectangle and round reflectors. When target outline physical structure appears corner reflector, backscattering is great strong and it appears very much bright line or point in SAR image. For example, vehicles and ground surface form dihedral corner reflector; wood in forest and ground surface makes up of dihedral corner reflector. For a piece of forest, when part forest is felled, there are corner reflectors and strong echo is produced. This makes the SAR image bring obvious change before and after fell.

2.4 Bulk scattering coefficient

The scattering echo signal of big area target comes from surface scattering or bulk scattering. When electromagnetic wave can penetrate ground objects, it brings bulk scattering. Bulk scattering is that the nonhomogeneity inside matter of ground object and the discontinuity of space position distribution create isotropy of bulk scattering. The intensity of bulk scattering is decided by the discontinuity of dielectric constant inside medium or nonuniform density; the scattering direction is determined by the geometry size between the mentioned nonhomogeneity and wavelength, or the correlation length of dielectric constant fluctuation and their space distribution direction. In a general way, bulk scattering is strong, the scattering attenuation of electromagnetic wave in medium is also strong, and correspondingly the penetration depth is less in medium.

2.5 Coherence of echo

The imaging principle of SAR is coherent imaging. When radar beam irradiates ground object surface, every resolution cell includes much of discrete scattering point, which is shown by Fig.3. Because electromagnetic wave and ground object mutually interact, each scatterer contributes one backscattering wave, whose phase and amplitude are variational. The echo is vector superposition sum between scatterer after they are coherent interaction. Single scatterer is much less than SAR resolution cell and none one scatterer lies in dominant position. Observed signal is the result of different phase coherence among scatterer. If the scattering cell or scattering structure of a target changes, whole backscattering coefficient also takes place change, which will cause SAR image change.

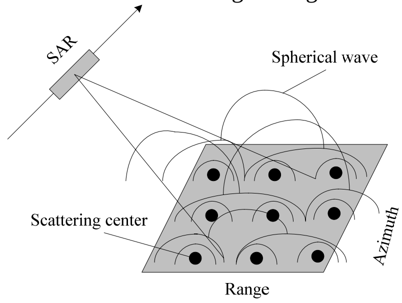


Figure 3 Coherent principle diagram of SAR imaging

From above analysis we know that the changes of target surface roughness, dielectric constant and target outline physical structure are the main factors that bring SAR image change. Roughness change leads to texture change of distribution target and they behave coherence change between scatterer in resolution cell.

3. CHANGE TYPE ANALYSIS OF SAR IMAGE

In SAR image change detection, sometimes SAR image changes, but ground objects don’t change, for instance, the growth status of the crop, the seasonal change of vegetation and forest. Although their relativities change, physical scattering structures don't almost change, namely, ground object types don't change. In some cases, the SAR images don't change, but the ground objects take place changes in fact, such as the change of crop types. In terms of whether or not ground object types, outline physical structures and scattering cell structures change, we make some analysis and classification for SAR image change.

(1) Ground objects thoroughly change from one type into another type, namely, it takes place qualitative change. For example, buildings turn into flats, or flats turn into buildings. Here, outline physical structures of ground objects are changed fundamentally and certainly its scattering cell structures bring thorough change. This leads to backscattering intensity, correlativity and texture feature changes, and all methods can detect the changes of ground objects.

(2) Ground object types don't change, but the outlines change, namely, it produces quantitative change. Ground object outline change leads to surface roughness change, but the physical structures don't almost change. So the scattering cell structures don't change, such as vegetated growth and forest seasonal change. Both their backscattering intensity and coherence change, but the texture features basically remain constant. Whereas，for leaf-fall forest seasonal change and desert surface change, their texture structures also change.

(3) The whole object type doesn't change, but local position takes place quantitative change and qualitative change. Here, both the outline and physical structures of ground object change, and texture features and scattering cell structures also change. Such as airfield, missile launch field and highroad, they are hit by battle or damaged by earthquake.

(4) Original ground object type doesn't change, but local object area brings qualitative change, namely, local part turns from one type into another type. For instance, crop is harvested, forest is felled, agricultural land is divided into many less block, and part of vegetable area type is moved or added. The correlativity, texture feature and scattering cell structure of local object area all change.

(5) Ground object type maybe changes, namely quantitative change or qualitative change happen probably. Their outline change in general and texture feature change is little, but physical structure doesn't change and scattering cell structure takes place change, such as grassland seasonal change; crop, vegetation and forest are suffer damage by insect.

4. THE ALGORITHM DESCRIPTION OF SAR IMAGE INTEGRATION CHANGE DETECTION

Although there are many kinds of SAR image change detection approaches, each method all has its advantage and disadvantage. At present, none one is the optimal method and there is no uniform standard. If only using one method, such as image grey difference algorithm, correlation coefficient algorithm or texture feature difference algorithm, describes SAR change, it is very inaccurate. For example, for the seasonal change of vegetation or forest, the scattering echo intensity changes, and the grey value and correlativity of SAR image pixel also change obviously, but their texture feature change less. Therefore, we should choose different detection means in terms of different aim and use or integrate the detected results of different methods. Otherwise, it often obtains poles apart detection results. The most used ways are image grey difference method, correlation coefficient method and texture feature difference method. Subsequently, we firstly study the principle and limitation of the three detection methods respectively, and then propose an applied integration SAR image change detection method on the basic of studying SAR image change mechanism and SAR change classification rule.

4.1 SAR image grey difference method

The grey difference method belongs to direct comparison means. The merits of this method are simpler theory, easy understand and good operation. But it can't confirm the change type. In other words, it is very difficult to confirm the property of change area and needs to further analyze change area. For instance, agricultural land and city land can be detected only as change land, but it is uncertain that agricultural land turns into city land or city land turns into agricultural land. If it need confirm the change type, we must use priori information or some relative information that other method acquires, and then further analyze it. At the same time, when the twice imaging conditions are different, for example, surface water content different, it can create grey difference, but it unnecessarily represents object change. In addition, it is very difficult to consider all influence factors for grey difference method. So it easily causes information capacity loss and demands higher registration accuracy for images. According to different detected objects, except for grey difference method, there is texture difference (Li, 2002; Chen, 2002), moment characteristic difference (Liu, 1998), vegetation indices difference, reflectance ratio difference, wavelet transform coefficient difference (Feng, 2004) and logarithm ratio difference.

Suppose X_{t1} and X_{t2} are the remote sensing images corresponding different t_1 and t_2 for the same sensor and scene area, respectively. After they are accurately registered, corresponding pixels make subtract operation. The definition is given by

$$D(i,j) = X_{t2}(i,j) - X_{t1}(i,j) + C \qquad (2)$$

Where, $D(i,j)$ is the pixel value of difference image, $X_{t1}(i,j)$ and $X_{t2}(i,j)$ are the pixel value of t_1 and t_2, respectively, C is constant. In the new produced difference image, the pixel values of no change area approach 0, and the pixel values of change area are positive or negative. In order to ensure pixel values more than 0, the constant C is often added or the equation makes absolute value. The equation is given by

$$D(i,j) = \left| X_{t2}(i,j) - X_{t1}(i,j) \right| \qquad (3)$$

If the grey value of a pixel in the difference image is more than threshold T_d , the pixel is thought change, or else no change. Using the corresponding pixel grey value direct subtracting, the effect is very bad. So it often uses a sliding window to compute the difference of the pixels.

4.2 Correlation coefficient method

Correlation coefficient method is to compute the correlation coefficient of corresponding multitemporal image pixel and the results represent the coherence. Because the correlation coefficient is invariable for grey linear variation, it can eliminate the differences of brightness and contrast between images that are caused by photography time and condition. If the multitemporal images change, the corresponding correlation coefficients also change. In the counting process, pixel (i, j) acts as a center to take a sliding window in general, computing the mean correlation coefficient of the corresponding window in the two images, the result acts as the center pixel coherence. If the correlation coefficient value closes 1, which shows the correlation high and the pixel doesn't change. Contrarily, it shows that the pixel changes. Suppose X_{t1} and X_{t2} are the remote sensing images corresponding different t_1 and t_2 for the same sensor and scene area, respectively. If X_{t1} and X_{t2} are complex SAR images, correlation coefficient can be computed by

$$C(i,j)=\frac{|\sum_{x,y\in A} X_{t1}(x,y)X_{t2}^{*}(x,y)|}{\sqrt{\sum_{x,y\in A}\left|X_{t1}(x,y)\right|^2}\cdot\sqrt{\sum_{x,y\in A}\left|X_{t2}(x,y)\right|^2}} \quad (4)$$

Where, A is the sliding window whose size is $M \times N$, (i, j) is center pixel. If X_{t1} and X_{t2} are not complex SAR images, correlation coefficient may computed by

$$C(i,j)=\frac{\sum_{x,y\in A}\left[X_{t1}(x,y)-\bar{X}_{t1}\right]\left[X_{t2}(x,y)-\bar{X}_{t2}\right]}{\sqrt{\sum_{x,y\in A}\left[X_{t1}(x,y)-\bar{X}_{t1}\right]^2}\cdot\sqrt{\sum_{x,y\in A}\left[X_{t2}(x,y)-\bar{X}_{t2}\right]^2}} \quad (5)$$

Where, $\bar{X}_{t1}$ and $\bar{X}_{t2}$ are the grey mean of sliding window, respectively. The correlation coefficient map is acquired and the judgment threshold T is designed. If $C \le T$, the pixel is change, contrarily, it doesn't change.

There are some factors that influence the correlation. (1) Change of incidence angle. The big change of incidence angle will bring powerful change for their correlation. Therefore, in change detection, it demands same or close incidence angle. (2) Type of ground objects. For example, if the type of ground objects is vegetable or forest, it will make the correlation rapidly fall because it grows. (3) The changing ground objects. For instance, the pass of vehicles and the implementation of building site, they also influence the correlation. (4) The natural factors. Such as the wheat land is been blowing by great wind and there is no wind in the wheat land, the correlation is obviously different. (5) Change of ground object azimuth angle. The big change of azimuth angle will bring obvious change for the correlation, so it demands the same or close azimuth angle in change detection.

4.3 Texture features difference method of SAR image

In SAR image change detection, it is insufficient to detect change only using the contrast of image grey and the texture features information ought to be utilized to detect change. The texture features of image describe the local mode of repeated appearance and their arrangement rule in image, which reflects some laws of grey change in macroscopical significance (Ruan, 2001). The usual definition of texture is some local properties of image or a measurement of relation between local pixels. And image can be seen as the combination of different texture area. Texture features may be used to quantitatively describe space information of image, and it is often related with the position, tendency, size and shape of object, but it is independent of mean grey level. The texture of image is not formalized, but it is relative with local grey and space organization.

There are eight statistic methods about image texture descriptions and measures, which are autocorrelation function, optimal transform, digital transform, textural edginess, structural element, gray-level co-occurrence matrix (GLCM), grey-level range and autoregressive model. In the following text, we will mainly introduce gray-level co-occurrence matrix method. GLCM emphasizes the spatial dependence of grey-level and the characteristic of it represents the spatial correlation of pixel grey under a sort of textural mode. The definition of GLCM is that each element (i, j) value in GLCM represents the frequency times of two pixels appearance under the pixel with value i occurred horizontally adjacent to a pixel with value j, neighbour distance value d and direction α in some size window. Each element value of GLCM can be computed by next equation.

$$P(i,j)=\frac{p(i,j,d,\alpha)}{\sum\sum p(i,j,d,\alpha)} \quad (6)$$

In order to reduce the burden of computation, the grey scales of original image should be adjusted. In the general, the grey scales of most images are 256 levels. If direct compute GLCM, it brings some difficulties. For a 256 levels grey image, the size of GLCM is 256×256 dimensions. But the texture features that we compute reflect the local characteristic of an image and it need not choose oversize window. There are large numbers of 0 values in 256×256 GLCM and it becomes sparse matrix. In this way, on the one hand it doesn't represent textures well, on the other hand it also makes a great many of wasting of resources. Therefore, before the GLCM is created, image grey levels are processed in order to reduce the dimensions of GLCM. For SAR image, the grey levels are adjusted to 8 or 16 and it doesn't damage textural information basically (Guo, 2000). Choosing the sliding window to compute GLCM is decided by image characteristics and extractive objects. That the size of window is small will ignores the correlation between pixels, which can't show the advantage of texture features. So the exactness ratio is lower when the size of window is small. With the window increasing, texture information gradually produces effect and the exactness ratio of change detection increases rapidly. When the size of window reaches some degree, the edge of image becomes blurring. It decreases the exactness of local image features and the pixel points of short distance bring confusion, which makes the exact ratio of change detection fall. The direction of GLCM little influences the computed value of characteristic quantity. The distance d usually only takes one or two in order that the textural measurement can be effectively connected with object features. The direction α generally chooses four directions: 0º,45º,90ºand 135º.

The GLCM can export a lot of texture features and their emphases are different, but many of them are relative. The textural feature difference fusion change detection algorithm that is proposed by this paper chooses five relatively independent textural features. Their definitions are given as follows (Baraldi, 1999).

(1) Contrast

$$f_{con}=\sum_{i,j}(i-j)^2P(i,j) \quad (7)$$

Contrast features reflect contrast intensity of neighbor pixels. The value is bigger, which shows that texture effect is more obvious; the value is less, which shows that texture effect is more indefinite. When the value is 0, it indicates the image is complete homogeneity and no texture. Contrast features have higher bright value at edge and inhomogeneous area.

(2) Energy (angular second moment)

$$f_{ene} = \sum_{i,j} P^2(i,j) \tag{8}$$

Energy features reflect grey distributing degree and texture thickness degree of image, which is also called angular second moment. When the image is uniformity, energy value is bigger. If the maximum value is 1, grey distributions are complete uniformity.

(3) Correlation

$$f_{cor} = \sum_{i,j} \frac{(i-\mu_i)(j-\mu_j)P(i,j)}{\sigma_i \sigma_j} \tag{9}$$

Where, $\mu_i = \sum_{i,j} iP(i,j)$, $\mu_j = \sum_{i,j} jP(i,j)$,

$\sigma_i = \sum_{i,j} (i-\mu_i)^2 P(i,j)$, $\sigma_j = \sum_{i,j} (j-\mu_j)^2 P(i,j)$.

$P(i,j)$ represents element (i,j) value in GLCM, μ_i and μ_j are mean, σ_i and σ_j are standard deviation.

Correlation features reflect the similar degree of GLCM element at row or column direction. It describes the periodicity of textural elements under some position relation.

(4) Entropy

$$f_{ent} = -\sum_{i,j} P(i,j) \log P(i,j) \tag{10}$$

The concept of entropy comes from information theory, and what it reflects is information content of image. That information content is big shows that entropy feature value is big, contrarily, it is small. If the uniformity of original image is better, entropy feature map is darker; if the uniformity is worse, entropy feature map is brighter.

(5) Homogeneity

$$f_{hom} = \sum_{i,j} \frac{P(i,j)}{1+|i-j|} \tag{11}$$

Homogeneity features are the measurement of image distribution smoothness. For homogeneous area, elements of GLCM gather at diagonal, $|i-j|$ value is small, homogeneous feature is big and the feature map is bright. For inhomogeneous area, elements of GLCM apart from diagonal, $|i-j|$ value is big, homogeneous feature is small and the feature map is dark.

Image textural difference method is similar image grey difference method, and just different textural feature map can produce a difference map. When using textural difference method detects change, what textural features are chosen for change detection is the important factor that decides the detection performance. This paper proposes a novel all features fusion algorithm, which is shown by Fig.4. Firstly, textural features difference map of multitemporal images are obtained, and the change of every feature map is detected. Then space position pixel (i,j) of all feature difference image is decided by vote, and each element is an alternative: change ω_c and no change ω_u . The most vote numbers $V_k(i,j), k=\{u,c\}$ that pixle (i,j) receives are acted as final clasifications, nemely, they are change type or no change type. They can be described by the next equation.

$$X_{TD}(i,j) \in \omega_k \Leftrightarrow \omega_k = \arg\max\{V_k(i,j)\}, k=\{u,c\} \tag{12}$$

Where $X_{TD}(i,j)$ represents the texture feature difference image.

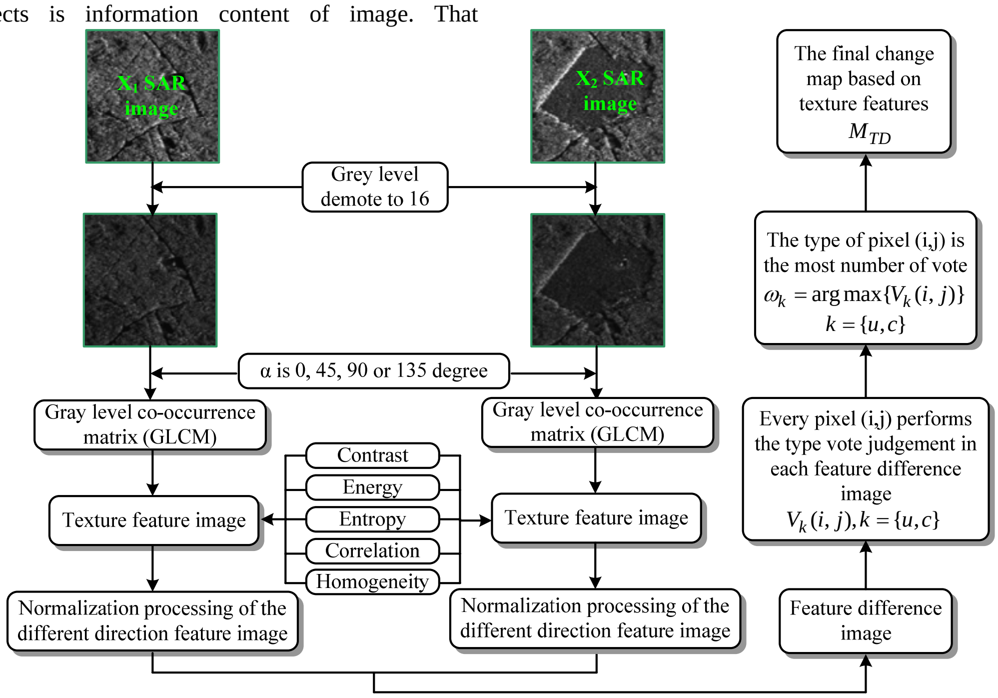


Figure 4 The change detection frame based on all texture feature fusion

4.4 Integration SAR image change detection method

Image grey difference method, correlation coefficient method and image textural feature difference method are based on pixel level change detection. They need strict registration and each method has advantage and limitation. Image grey difference method is the simplest and it is particular sensitivity to grey change. Grey is backscattering intensity measurement of ground objects, which is influenced by some factors such as surface roughness, dielectric constant and corner reflection effect, and they have been studied in detail in SAR image change mechanism. For grey difference method is the change parameter that is used to describe grey, it easily brings false alarm change. For example, crop growth state, vegetable and forest seasonal change. The textural difference reflects grey space distribution law and the false alarm change is relatively small. But the computation is relatively complex and the change detection results have errors, such as leaf-fall forest seasonal change or suffering from insect disaster and outline change of desert. Therefore, there is none one method that has been optimal by far and no a uniform standard. Especially, in SAR image, the complex imaging principle leads to the change complex.

The imaging mechanism of SAR is different optical and infrared remote sensing image. The typical distinction is that SAR image contains abundant speckle noise, which is inevitable. Therefore, it very difficultly obtains ideal effect for general change methods that are used to SAR image. With the development of multi-frequency, multi-platform, multi-angle of view and multi-polarization SAR, the repeat visit period of SAR carrier is shortened and SAR has the characteristic that can acquire data under all-time and all-weather, SAR images are very important remote sensing change detection information source, which has great potential application. However, SAR image processing is relatively complex, and this obstructs extensive application of SAR image change detection. For SAR image change detection, according to practical application purpose and correlative prior information, we will get relative ideal detected results. This paper proposes an integration SAR image change detection method in terms of SAR image change mechanism and change classification rule, which is shown by Fig.5.

It is seen from the Fig.5 that the change of surface parameters finally causes SAR image change. Only using single method to detect change, we don't obtain more precise change result map until it combines SAR image change type and correlative prior information. For example, for the growth state evaluation of the crop, the prior information is crop. It should belong to the kind that the type doesn't change from change type analysis, but the outline takes place change, namely, it takes place quantitative change without qualitative change. Textural structure doesn't change almost, but the correlation coefficient and backscattering intensity change obviously. So the grey difference method and the correlation coefficient method are utilized to detect change. If only grey value changes and the correlation coefficient do not change, a judgment is decided that the crop doesn't change; if the correlation coefficient also change, this shows that the crop object area assuredly change. If using textural feature difference method judges, the result is no change.

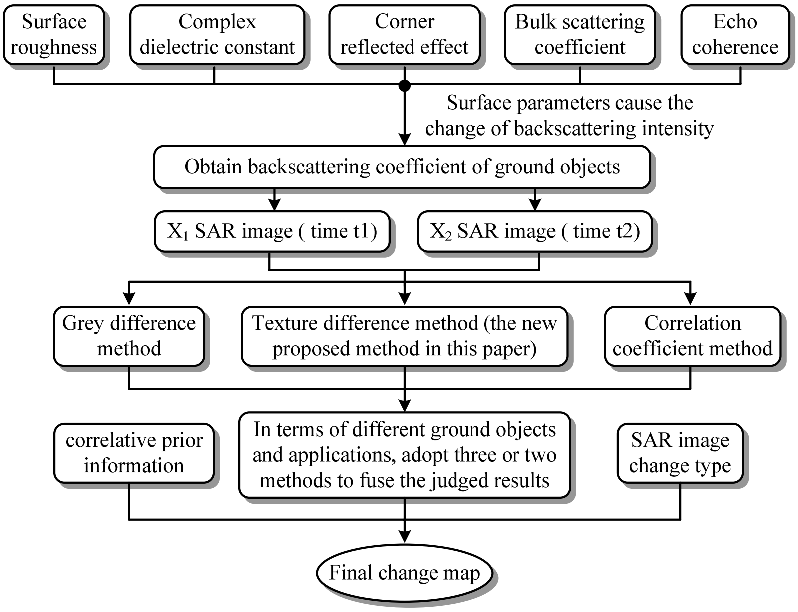
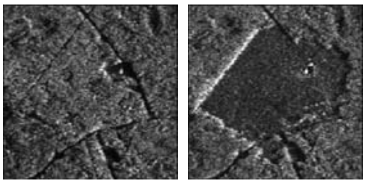


Figure 5 The flow chart of the integration SAR image change detection algorithm

5. EXPERIMENTAL RESULTS

Suppose that the SAR images at different date t_1 and t_2 are X_1 and X_2, respectively, and they are revised by radiation and geometry and registration. The grey difference method, the correlation difference method and the texture difference method all need come into being one judgment threshold and the expectation maximization (EM) algorithm is used to estimate the threshold in this experiment (Moon, 1996). Experimental data adopts the remote sensing data of Canada centre for remote sensing airborne C/X-SAR (http://ccrs.nrcan.gc.ca/radar /airborne/cxsar/sbfort_e.php.). The original images are shown in Fig.6. Where, Fig.6(a) and Fig.6(b) are different date single SAR images, which are C wave band HH polarization image and space resolution is $5m \times 5m$. The imaging dates of Fig.6(a) and Fig.6 (b) are Mar. 18, 1991 and Feb. 8, 1992, respectively. Hypothesis Fig.6(a) is X_1 at time t_1 and Fig.6(b) is X_2 at time t_2 . The area is a piece of forest. Because the frost is fallen, ground object type takes place change, but its scattering structures don't change. This leads to final SAR image change. The scattering intensity of forest is stronger than that of bare ground surface. So after the forest is fallen, the backscattering intensity becomes weak. In SAR image, it indicates dark, which is shown in Fig.6(b). The brighter line area in the centre of



(a) Before change (b) After change

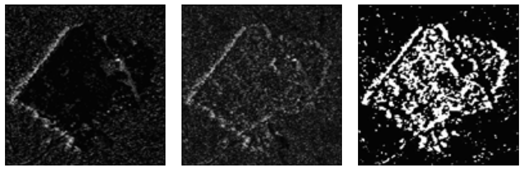
Figure 6 The SAR images before and after change

Fig.6(b) is dihedral reflection effect between ground surface and forest. It belongs to strong scattering structure and the echo intensity is bigger, which is brighter in SAR image.

The change detected results with the grey difference method are shown in Fig.7. Where, Fig.7(a) is the difference image X_D of X_2 and X_1, namely, $X_D = X_2 - X_1$; Fig.7(b) is absolute value of X_D, i.e. $|X_D|$; Fig.7(c) is the detected results with single threshold grey difference algorithm. Fig.8 is the detected results with correlation coefficient method. Where, Fig.8(a) is the correlation map of coefficient between X_2 and X_1. Fig.8(b) is the detection results with correlation method and the threshold is $T = 0.6$.

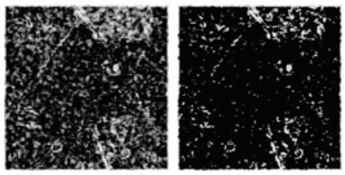
The change detection results with textural feature difference method are shown in Fig.9. Where, Fig.9(a) and Fig.9(b) are the images that grey levels are decreased into 16 levels. Fig.9(c)-(g) and 9(h)-(l) are the corresponding contrast map, correlation map, energy map, entropy map and homogeneity map of image X_1 and X_2, respectively. Fig.9(m)-(q) are the detection result maps contrast map, correlation map, energy map, entropy map and homogeneity, respectively. Fig.9(r) is the detection results with the textural feature fusion algorithm proposed by this paper.

It is seen from the above experimental results that there is no method can detect whole changes, so it doesn't obtain relatively



(a) (b) (c)

Figure 7 The detection results with grey difference method, (a) Difference image, (b) The absolute values of difference image, (c) The results of change.



(a) (b)

Figure 8 The change detection results with correlation coefficient, (a) The correlation map of coefficients,(b) The change detection result map with $T = 0.6$

precise detection results until the advantage of all algorithms is fused. The experimental area belongs to the case that theoriginal ground object type doesn't change, but the local area takes place qualitative change, i.e., the forest is felled. Therefore, the relativities, the texture features and the scattering cell structures of the local object areas all change, which is shown by Fig.7, Fig.8 and Fig.9. If we know in advance that the detected area is a piece of forest (prior information), the right judgment can be performed to the object change. For example, the bright line is the dihedral effect between forest and ground, and it is obviously shown by Fig.9(m) in the contrast detection of texture features. The center part of the image X_2 is dark, not only their correlative coefficients are very low, but also can the change be detected in both gray and texture difference approaches, which illuminates that the area really changes.

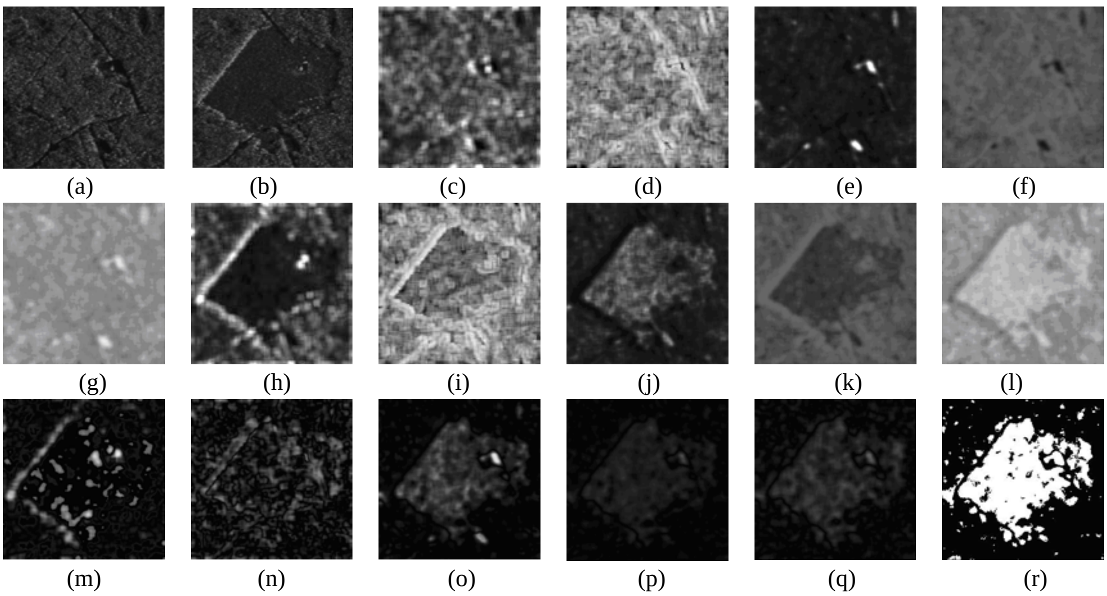


Figure 9 Textural features change detection,(a) 16 levels grey image of X_1 image, (b) 16 levels grey image of X_2 image, (c) contrast map of X_1, (d) correlation map of X_1, (e) energy map of X_1, (f) entropy map of X_1, (g) homogeneity map of X_1, (h) contrast map of X_2, (i) correlation map of X_2, (j) energy map of X_2, (k) entropy map of X_2, (l) homogeneity map of X_2,(m) detection resuts of contrast，(n) detection resuts of correlation，(o) detection resuts of energy，(p) detection resuts of entropy，(q) detection resuts of homogeneity，(r) detection resuts of the proposed texture feature fusion.

6. CONCLUSIONS

This paper deep studies the change mechanism of SAR images, analyzes the change type of SAR images in terms of practical instances and discusses three typical change detection methods of SAR images which are the gray difference method, the correlative coefficient method and the texture feature difference method. In the difference change detection of texture features, a new change detection algorithm is proposed via fusing all texture features. What is more, an integrative SAR image change detection algorithm is presented in light of the change mechanism and change type of SAR image. Some real SAR images are used to test the proposed approaches and the experimental results show they are feasible. Future developments of this work are how to reduce the influence that SAR image speckle noise brings to SAR image change detection.

References

Baraldi A., Parmiggiani F., 1999. An investigation of the textural characteristics associated with gray level cooccurrence matrix statistical parameters. IEEE Transactions on Geoscience and Remote Sensing,33(1), pp. 293-304.

Bruzzone L., Serpico S. B., 1997. An iterative technique for the detection of land-cover transitions in multispectral remote sensing images. IEEE Transactions on Geoscience and Remote Sensing, 35(4), pp. 858-867.

Castellana L., Addabbo A. D., Pasquariello G., 2007. A composed supervised/unsupervised approach to improve change detection from remote sensing. Pattern Recognition Letters, 28, pp. 405–413.

CCRS C/X Band SAR · Forestry. http: // ccrs. nrcan.gc.ca /radar /airborne /cxsar /sbfort_e.php.

Chen F. L., Zhang H., Wang C. 2007. The art in SAR change detection-a systematic review. Remote Sensing Technology and Application, 22 (1),pp. 109-115. (in Chinese))

Chen F., Luo L., Yaqiu J. I., 2004. Automatic analysis of change detection of multi-temporal ERS-2 SAR images by using two-threshold EM and MRF algorithms. Progress in Natural Science, 14(3), pp. 269-275.

Chen Z. .P, Deng P., Chong J. S., 2002. Application of textural features to change detection in SAR image. Remote Sensing Technology and Application, 17(3), pp.162-166. (in Chinese)

Eric J. M. Rignot and Jakob J. van Zyl. Change Detection Techniques for ERS-1 SAR Data. IEEE Transactions on Geoscience and Remote Sensing. 1993, 31(4): 896-906.

Francesca B.,Lorenzo B., 2005. A detail-preserving scale-driven approach to change detection in multitemporal SAR images. IEEE Transactions on Geoscience and Remote Sensing, 43 (12), pp. 2963-2972.

Feng D. I., Li Y. S., Deng F., 2004. Detecting change information automatically by method of wavelet coefficient difference. Remote Sense Information, 2, pp.13-15. (in Chinese)

Fu W. X., Li S. H., Hong W., 2003. Hitting effect evaluation based on high-resolution SAR images. Acta Electronica Sinica, 31(9), pp.1290-1294.

Gabriele M., Sebastiano S., Gianni V., 2007. Unsupervised change detection from multichannel SAR images. IEEE Transactions on Geoscience and Remote Sensing Letters, 4(2), pp. 278-282.

Guo H. D., et al. 2000. Radar for earth observation: theory and application. Science Publishing House, Beijing, China.

Huang S. Q., Liu D. Z., Chen L., 2007. A study of the damage detection method for smooth earth surface. Acta Geophysica Sinica, 50(4), pp. 315-321.

Inglada J., Mercier G., 2007. A new statistical similarity measure for change detection in multitemporal SAR images and its extension to multiscale change analysis. IEEE Transactions on Geoscience and Remote Sensing, 45 (5), pp. 1432-1445.

Jiang L., Liao M. S., Zhang L., Lin H., 2006. Change detection in multitemporal SAR images using MRF models. Geomatics and Information Science of Wuhan University, 31(4), pp. 312-315.

Lu D., Mausel P., Brondi Z. E., 2004. Change detection techniques. International Journal of Remote Sensing, 25(12), pp.2365-2407.

Li L. Y., Maylor K., Leung H., 2002. Integrating intensity and texture differences for robust change detection. IEEE Transactions on Image Processing , 11(2), pp. 105-112.

Lorenzo B., Diego F. P., 2000. Automatic analysis of the difference image for unsupervised change detection. IEEE Transactions on Geoscience and Remote Sensing, 38(3), pp. 1171-1182.

Liu S. C., Fu C. W., Chang S., 1998. Statistical change detection with moments under time-varying illuminations. Transactions on Image Processing, 7(9), pp. 1258- 1268.

Merril K. R., Jiajun L., 1998. A comparison of four algorithms for change detection in an urban environment. Remote Sensing Environment, 63(2), pp.95-100.

Oliver C., Quegan S., 1998. Understanding synthetic aperture radar images. Artech House, Boston.London.

Quegan S., Toan T. L., Yu J. J., Ribbes F. and Floury N., 2000. Multitemporal ERS SAR analysis applied to forest mapping. IEEE Transactions on Geoscience and Remote Sensing, 38(2), pp.741-753.

Paolo G., Fabio D. A., Giovanna T., 2007. Rapid damage detection in the bam area using multitemporal SAR and exploiting ancillary data. IEEE Transactions on Geoscience and Remote Sensing, 45(6), pp.1582-1589.

Ruan Q. Q., 2001. Digital Image Processing. Publishing House of Electronics Industry, Beijing, China.

Moon T. K., 1996. The expectation-maximization algorithm. Signal Processing Magazine, 13(6), pp.47-60.

US office deal with roadside bomb with unmanned aerial vehicle synthetic aperture radar. http://jczs.news.sina.com.cn /p/2006-11-05/0735409951.html.

Zhang H., Hu N., Liu G., 2005. Application of multitemporal composition and classification to land use change detection. Geomatics and Information Science of Wuhan University, 30(2), pp.131-134. (in Chinese)