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Information Extraction of Building Set of SAR Image Based on Genetic Algorithm

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Abstract
Due to the problem of low level of accuracy and practicability in the existing method, this paper puts forward geometric information extraction framework of buildings based on the matching degree of model and image. On one hand, this framework maps building model to image to determine the typical feature region of the image which contains the geometrical information of buildings, such as overlapping and shadow region, on the other hand, it makes use of building contour and other information obtained from the building detection stage to find the best model parameters through the matching degree of the two. The new framework is applied universally. Geometric model of building parameters, typical feature region and the extraction method could all be adjusted in accordance with practical application. Take the most commonly seen flat topped buildings as an example; it discussed a specific application of the framework: under the condition of different imaging parameters and model parameters, it analyzed in detail the method of mapping building model into of overlapping and shadow typical feature region of images; it designed the matching degree of overlapping boundary and shadow boundary to measure the matching degree between the model and the image; The optimization method based on genetic algorithm is presented. The model parameters which enable the maximum matching function are used as the geometric parameters

of the targeted building. Experimental results of simulation and experimental data show that the precise mapping from building geometric model to image in the new method could ensure the accuracy of the solution; in addition, the problem of extracting geometrical information is transformed into the problem of maximizing the matching degree function, then we can use optimization algorithm find solutions automatically without artificial calculation, thus improving the practicality greatly.
Key words: MODEL AND IMAGE; BUILDING DETECTION, EXTRACTION METHOD, GENETIC ALGORITHM

1. Introduction

As an active microwave remote sensing device, SAR, compared with the traditional optical imaging system, is characteristic of all-day reconnaissance and strong surface penetrating ability. Therefore, it plays an important role in remote sensing observation system towards earth and is widely used. Information extraction of urban environment usually focuses on artificial targets in cities and buildings are one of the most important features in high-resolution urban images. It is of great implication in military surveillance, tracking, mission planning, training and loss estimation to extract buildings from urban environment; it is also widely used in map drawing, land use survey and urban planning etc; in particular, with urban economic development in recent years, natural resource allocation, environmental protection and other issues have drawn more and more attention, and this places high demand for information of urban geographical environment change, one of which is extraction of building information.

One key subject of SAR image information retrieval is to obtain 3D geometric information of buildings using SAR image. After we detect buildings, a further step to extract their 3D geometric information could provide effective features for practices like building identification. Similar to the building detection, this subject requires that SAR image has high resolution [3]. Therefore, related studies have not been carried out until the emergence of high resolution SAR sensor recently. Geometric information acquisition of buildings from a single SAR image is often the basis of other methods (such as from multiple images). However, related research on single SAR image still stays in the stage of measuring overlapping and shadow information for building geometric parameter estimation. Its main problems in practical application are [4-5]:1.Usually we only use the projection relation of buildings' section perpendicular to azimuth during imaging (corresponding to a transversal in an image) to estimate the parameters. However, buildings' section changes segment by segment when azimuth coordinate changes, so we can not use a simple formula to estimate geometric parameters. Usually this method requires that buildings are parallel to azimuth. But this premise is not necessarily achieved in practice. 2.The use of overlapping and shadow information is often separated. As a result, part of the study focused on the extraction of buildings' height information, rather than parameter estimation of overall building model. 3. There is a lack of study on precise positioning of overlapping and shadow. If the positioning error turns out to be significant, it is bound to cause the error in geometric parameter estimation. In view of the above problems, this chapter introduces an extraction method of building geometric information based on matching degree between models and images. On one hand, the overlapping and shadow region is projected onto the image in accordance with building parameter model; on the other hand, we conduct feature extraction of overlapping and shadow region for the image (including information about boundary and contour). The two is linked by designing matching degree function, and then we find solutions of geometric parameters which make the model and the image mostly matched [6]. The use of building parameter model and imaging relationship enables the angle deviation (azimuth) between building trend and direction to be introduced into geometry information extraction process as a variable, thus we no longer need to set a limit to the relationship between direction and building trend; we obtain overlapping and shadow region as a whole and highlight the exact boundary location of the overlapping and the shadow region with the help of image of boundary contour and edge strength obtained through building detection. And the combination of the two can improve the reliability and accuracy of geometric parameters estimation.

2. Determination of the position of the overlapping and the shadow region of flat topped buildings

The overlapping and shadow region of flat topped buildings contains building's geometric information. Therefore, after determining the geometric model of building parameters, we mainly make comparisons between the overlapping and shadow information from model mapping and information from actual images. In the following part, we firstly discuss about how to determine the corresponding position of building overlapping and shadow mapping to the slant range image, given the known geometry parameters of the building. What is needed to explain, before the derivation of geometric mapping relationship, is that this derivation and the subsequent application in building geometry information extraction are based on the following premises:

1). The image used in building geometry information extraction is a sliced image containing a single building. (Can be obtained either after building detection or by artificial selection on the big image)

2). The roof of flat topped building mainly shows specular reflection. The most prominent feature of the building on the image is the highlighted overlapping region and black shadow region.

3). In sliced image, the overlapping and shadow region of the building are complete. If not, there must be a significant error for the corresponding geometric parameters estimation [7].

2.1 Parameterization geometric model of buildings

In order to describe buildings quantitatively, we define a set of parameters as follows to represent a building in a scene:

$$M_b \overset{\Delta}{=} (x_0, y_0, \varphi, L_b, W_b, H_b)$$

L_b, W_b, H_b are parameters related to building model itself, which represent Length, width, height of the building (as shown in Figure 1). x_0, y_0, φ are location parameters and azimuth of the building model in the scene, the projection of the building on the ground is a rectangle.

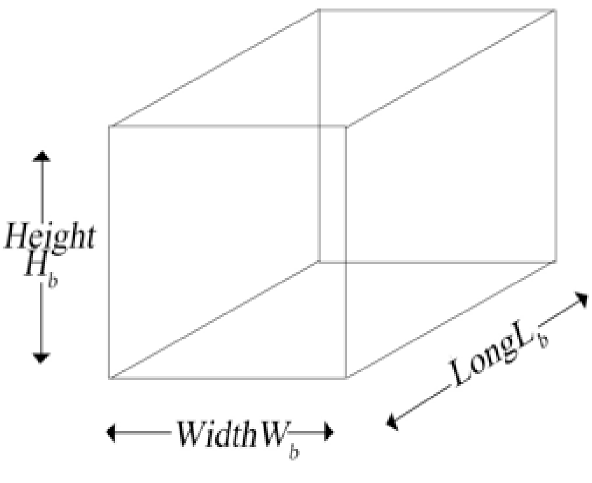

Figure 1. Three-dimensional spatial model of the flat topped building

For the convenience of description, we specify that any building is made from a building, whose long side is parallel to the direction, rotating around its axis for a certain angle. Central coordinate of the rectangle is (x_0, y_0). Assume the coordinates of four vertices v_1, v_2, v_3, v_4 are $(x_1, y_1), x_2, y_2, (x_3, y_3), (x_4, y_4)$ respectively, the coordinate values can be easily obtained from parameters of the building:

$$\begin{cases} x_1 = x_0 - \frac{1}{2}W_b\cos\varphi - \frac{1}{2}L_b\sin\varphi \\ y_1 = y_0 - \frac{1}{2}W_b\sin\varphi + \frac{1}{2}L_b\cos\varphi \end{cases}$$

$$\begin{cases} x_2 = x_0 - \frac{1}{2}W_b\cos\varphi + \frac{1}{2}L_b\sin\varphi \\ y_2 = y_0 - \frac{1}{2}W_b\sin\varphi - \frac{1}{2}L_b\cos\varphi \end{cases}$$

$$\begin{cases} x_3 = x_0 + \frac{1}{2}W_b\cos\varphi + \frac{1}{2}L_b\sin\varphi \\ y_3 = y_0 + \frac{1}{2}W_b\sin\varphi - \frac{1}{2}L_b\cos\varphi \end{cases}$$

$$\begin{cases} x_4 = x_0 + \frac{1}{2}W_b\cos\varphi - \frac{1}{2}L_b\sin\varphi \\ y_4 = y_0 + \frac{1}{2}W_b\sin\varphi + \frac{1}{2}L_b\cos\varphi \end{cases}$$

2.2 The mapping relation from building section to slant distance image

Under front view and side view, we can assume that the overlapping and shadow scope of a building depends on the mapping relationship from buildings' sectional view along the azimuth direction to the image. For a flat topped building, its sectional view along the azimuth direction is a rectangle, as is shown in figure 2. A and B are located on the vertical wall of the building towards the sensor, corresponding to the corner of wall and edge of roof. C is located on the vertical wall of the building against the sensor, corresponding to the edge of roof. The distance between A, B, C to the sensor determines the location of the overlapping and shadow region of the building. Depending on the distance between A, C and the sensor, two different cases have to be considered in the analysis of the projection relationship of cross section of the flat topped building.

When the distance between sensor position F and the building's corner A is greater than the distance between F and edge C on the vertical wall which is against the sensor:

$$FA \geq FC$$

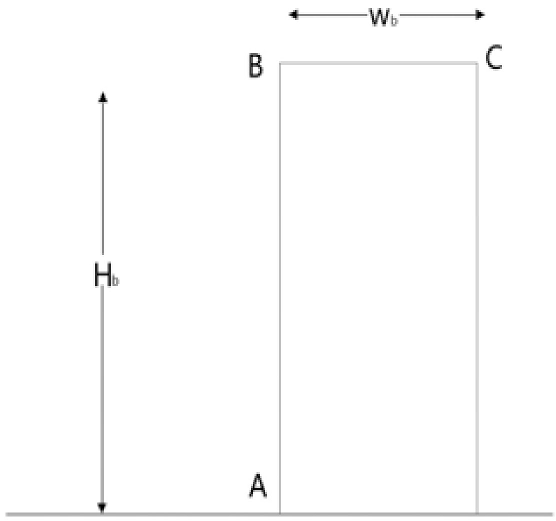

Figure 2. Sectional view of the flat topped building

In this situation, the starting and ending positions of the building's overlapping region are determined by the upper edge B of the vertical wall and the corner position A respectively. The slant distances are respectively:

$$r_B = \sqrt{\left(x_O^* - x_S - \frac{W_b^*}{2}\right)^2 + \left(z_S - H_b\right)^2}$$

$$r_A = \sqrt{\left(x_O^* - x_S - \frac{W_b^*}{2}\right)^2 + z_S^2}$$

The starting position of the building's shadow region corresponds to the ending position of the building's overlapping region, while the ending position of the shadow region is dependant upon edge C on the vertical wall which is against the sensor. Make a line from sensor position F to C, and intersect with the ground on point D. Assume coordinate of D on X axis is Dx, according to occlusion relationship, we have:

$$\frac{x_D - x_o^* - \frac{W_b^*}{2}}{x_D - x_S} = \frac{H_b}{z_S}$$

Can obtain

$$x_D = \frac{\left(x_o^* + \frac{W_b^*}{2}\right) \cdot z_S - H_b \cdot x_S}{z_S - H_b}$$

Then the oblique distance corresponding to the end of the shadow is

$$r_D = \sqrt{\left(x_D - x_S\right)^2 + z_S^2}$$

Based on above analysis, when radar imaging parameters and models and parameters of the building are known, the position of the overlapping and shadow region of the building on slant distance image can be determined.

3. Design of matching degree function between building model and on-the-spot measurement image

The specific method of mapping the overlapping boundary onto the image has been given. We need to compare it with the actual overlapping boundary on the image. Since the building detection method proposed in chapter 4 of the paper can locate the outline of the building target precisely, contour here is actually the contour of the strong scattering region caused by overlapping.

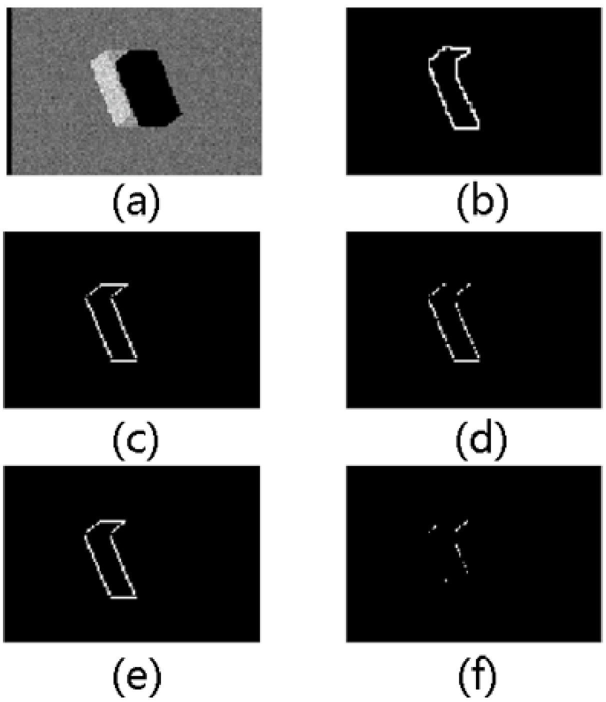

Figure 3. A sketch map illustrating single pixel contour not suitable for direct reference profile

(a) Simulation map. (b) Detected single pixel contour of the overlapping region. (c) Contour of the overlapping region obtained from actual parameter model mapping. (d) Take (b) and (c) intersection. (e) Mapped contour of overlapping region from disturbed model. (f) Take (b) and (E) intersection, i.e. the overlapping region from detected contour and mapped contour out of disturbed parameter model.

Therefore, the actual reference information of the overlapping boundary can be obtained from boundary contour through building detection. Affected by noise and quantization error etc, the boundary contour obtained by building detection is usually not the same with real boundary, and there is an error. And the boundary contour is single pixel wide. If this contour is used directly as the reference overlapping boundary in the image; the overlapping boundary out the model is mapped onto the image then and when matching degree is measured by overlapping degree, the matching degree could be much low even if model parameters are very close to actual parameters. In the following, we use simulation image to make illustrations. Figure 3(a)is a simulation image of a building, and its actual model parameters are $(x_0, y_0) = (100, 50)$ $L_b = 40m$, $W_b = 15m$, $H_b = 20m$, $\varphi = 30°$. Figure 3(b)is detected contour of overlapping region using methods from chapter 4, figure 3(c)is the overlapping boundary mapped onto the image by the actual model. Figure 5.14(d)is the overlapping part of detected overlapping region contour and the overlapping region contour out of the model's mapping, and the pixel in the overlapping part is 72% of the total pixel of mapped overlapping region contour. Then we added a small disturbance to actual model parameters. Move the building's ground center to the scene's coordinate system origin by one pixel, i.e. $(x_0', y_0') = (99.49)$, overlapping boundary from disturbed model mapping onto the image is in figure 3(e). Figure 3(f)gives a overlapping part of itself and detected overlapping boundary. At this time, pixel in the overlapping part is only 16% of total pixel of overlapping region contour from disturbed model mapping. We can see that when we use detected single-pixel-wide contour as real reference contour information, a small change in model parameters could cause significant change in matching degree. And this is not good for optimization search.

In particular, since overlapping region reflects the height information, height estimation can be performed by using the overlapping boundary matching degree only. The estimation of other parameters is not reliable due to the existence of multiple solutions. Likewise, all parameters can not be precisely estimated only by using matching degree of shadow boundary. Therefore, the matching degree function must be obtained by combining the information of overlapping and shadow. Since the variation range of matching degree function of overlapping boundary $E_0(M_b, f)$ and matching degree function of shadow boundary $E_s(M_b, f)$ are all [0,1], we can define the overall matching degree function by simple weighted sum:

$$E(M_b, f) = k_0 E_0(M_b, f) + k_s E_s(M_b, f)$$

Where, k_0 and k_s are $E_0(M_b, f)$ and $E_s(M_b, f)$ respectively. weight factor used to adjust their proportion.

Based on previous analysis, the matching of overlapping boundary position is based on the matching of detected results. It is possibly a building only if matched in the overlapping boundary position. The matching of the shadow boundary can be considered as a criterion to judge whether the results are in line with actual situation.

4. Objective function optimization based on genetic algorithm

We use the defined matching degree function to establish the link between the building model and on-the-spot measured image. So the problem of building geometric information extraction is transformed into the optimization problem of maximizing the matching function. Obviously, the calculation in the matching degree function involves the mapping relation between the model and the image and is relatively complicated. The optimal solution can not be acquired directly. A feasible way is to generate the initial value of the model parameters. Following the matching degree, we adjust the parameter value to make it towards optimal solution. Genetic algorithm is an important method to solve this problem. Compared with traditional optimization algorithms, genetic algorithm is not restricted to search space (Continuous, derivative exists, single peak etc.) and the calculation is simple. It provides a general framework for solving optimization problem of complex systems. It is robust to different kinds of problems and especially suitable for complex and nonlinear problems which are difficult to solve by traditional search methods. Genetic algorithm is an adaptive and global optimized probability search algorithm by simulating creatures in genetic and evolutionary processes in natural environment. Generally the solution seeking includes the following several aspects: Chromosome encoding, Population initialization, Design of fitness function, Determination of genetic operators and set of termination conditions.

4.1 Chromosome encoding

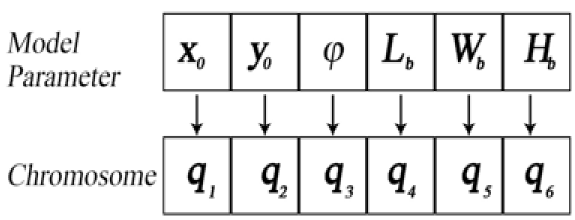

Figure 4. Chromosome encoding mode

Encode every possible solution into a vector, which is called a chromosome or an individual. Eachelement of the vector is called a gene. Since the model parameter to be solved $M_b \stackrel{\Delta}{=} (x_0, y_0, \varphi, L_b, W_b, H_b)$ consists of 6 real valued variables, we use real number encoding mode. Each gene of an individual is represented by a real number in a certain range. Encoding length of an individual is equal to the number of its variables. Specifically, each chromosome is represented by a real number vector $Q=(q_1,q_2,q_3,q_4,q_5,q_6)$ whose length is 6 and corresponds to 6 parameters $x_0, y_0, \varphi, L_b, W_b, H_b$ respectively, as shown in Figure 4. The range of the values in the chromosome is restricted by the corresponding parameter range.

4.2 Population initialization

In the process of genetic algorithm, the task after encoding designing is the setting of initial population and evolving by generation until coming to an end by some evolution termination rule. Here we use the most commonly used method of random initialization. Assume the population size is N_{pop}, and randomly generate 5 chromosomes whose length is 6. Each of the value range in the chromosome is also restricted by the corresponding parameter range. In order to ensure the diversity of individuals in the population, this paper sets N_{pop} = 100.

4.3 Fitness function

Fitness is the degree of measuring an individual arriving or close to the optimal solution in genetic algorithm, and also the basis for optimization process development of genetic algorithm. An individual with higher degree of fitness has a high probability of transmitting to the next generation. The defined matching function is used directly as the fitness function. When calculating the fitness function, the value of each gene of chromosome, as the corresponding model parameters, is brought into the formula:

$$E(M_b, f) = k_0 E_0(M_b, f) + k_s E_s(M_b, f)$$

4.4 Genetic operators

In genetic algorithm, selection operator is used for selecting the fittest individual in a group in accordance with the fitness of the individuals. In order to avoid premature phenomenon, Boltzmann probability selection mechanism in simulated annealing is introduced. Assume the fitness of individual i in k generation is E_i, and the probability of it being selected is

$$P_{si} = \frac{\exp\left(\frac{E_i}{T_i}\right)}{\sum_{j=1}^{N_{pop}} \exp\left(\frac{E_j}{T_k}\right)}$$

The termination condition of the algorithm is set as: when iteration times in genetic algorithm reaches the maximum pre-set times MaxGen, or the optimal individual in continuous NC generations cease to change. In this paper, $MaxGen = 300$, $N_0 = 50$.

5. Experimental results and analysis

In order to verify the effectiveness of the new method, the simulation image is firstly experimented: under the condition of equal weighted overlapping and shadow matching degree, the new method is used to extract the geometrical information of multiple buildings in different azimuths and the estimation error is analyzed. We discussed that when the relative weights of the overlapping and shadow matching degree change, how the change would affect algorithm performance, including two special cases of only using either overlapping information or shadow information. The extraction result from the new method is compared with estimation result from the direct measurement method. Finally, based on the analysis of the simulation experiments, the new method is applied to the on-the-spot images.

Figure 5 (a) gives the outline of the target obtained by using building detection method in chapter 4, i.e. corresponding to the overlapping and shadow region of the building. Figure 5 (b) is the result of an expansion of the target contour. Figure 5 (c) gives the original edge map. After removing the edge pixels in the target contour range of Figure 5 (b), an expansion operation is performed on the remaining edges (see Figure 5 (d)), then we obtain the edge map in figure 5(e), which is used in the calculation of matching degree of shadow boundary. In the calculation of the matching function (i.e. fitness function in the genetic algorithm), the weight values of matching degree of overlapping boundary and shadow boundary are set as $k_0 = 1$ and $k_S = 1$, i.e. the performance of the algorithm is considered in the case of the same weight of the two. Figure 6 shows the fitness of each optimal individual in the process of evolution of the genetic algorithm. It can be seen that the algorithm converges quickly and the time of the entire optimization process is 49.6 seconds.

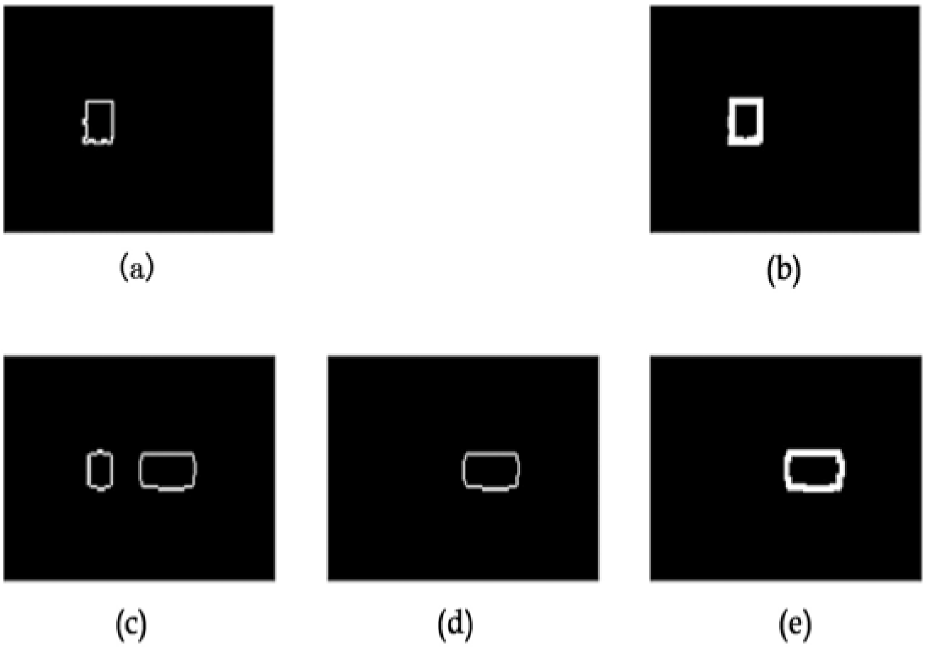

Figure 5. Feature map used to calculate the matching degree function (ϕ =90)

(a) The target contour detected. (b) Expansion results of target contour. (c) Initial two valued edge map. (d) Removing edge pixels in the range of the target contour in (b). (e) Residual edge expansion.

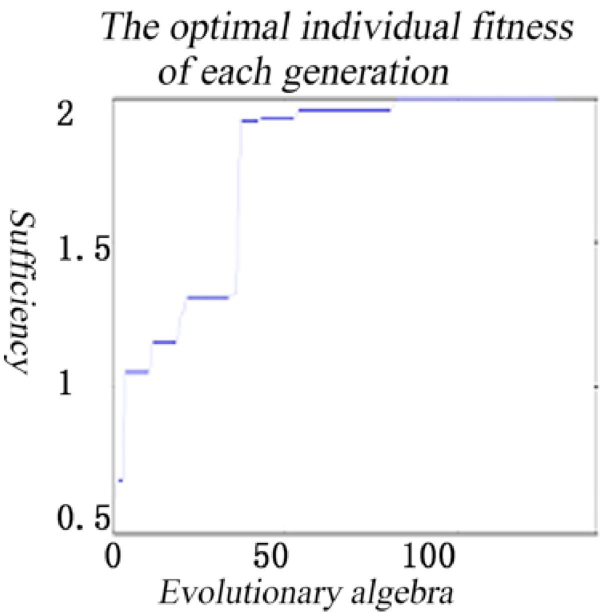

Figure 6. The optimal individual fitness of each generation in the process of genetic algorithm optimization

In the process of solving building geometric parameters, it is inevitable to introduce these errors, which will affect the results of the estimation of the parameters. However, in general, based on the accuracy assessment results in related literatures at present, the method of this paper can effectively extract the geometric information of buildings. For example, literature [8] uses a multi view image to estimate the geometric parameters of buildings. In the experiment of simulation map of two buildings, the maximum error of the center position, azimuth, length, width and height of the building is 1.2 meters, 1.5 meters, 0.4 degrees, degrees, 2 meters, 2.5 meters and 1.1 meters respectively. Although the method in this paper uses only a single image, the accuracy of parameter estimation is close to the accuracy in literature [8]. As shown in Table 1:

Table 1. Estimation results of building geometric parameters of the simulated image

Actual azimuth (degree)	Parameter estimation					
	x_0 (meter)	y_0 (meter)	φ (degree)	L_b (meter)	W_b (meter)	H_b (meter)
0	100.4	49.8	-0.2	40.1	15.7	19.4
30	99.9	50.4	27.4	40.4	15.9	18.7
60	99.4	50.3	27.4	37.4	13.7	20.7
80	100.0	50.1	57.3	37.1	16.1	20.9
90	98.7	50.3	89.9	40.4	16.2	18.5
-30	99.3	49.6	-31.8	38.7	15.2	19.8
-45	100.0	49.7	-44.8	38.5	16.3	19.4
-75	99.3	50.1	-75.3	36.3	15.5	20.7
True value	100	50	—	40	15	20
Maximum absolute error	1.3	0.4	2.7	3.7	1.3	1.5
Mean absolute error	0.5	0.3	1.2	1.6	0.9	0.8

Direct measurement method is used in Figure 5 (a). The length and width of the building are determined by measuring the length of the two edges of the L – shape in overlapping region. The height of the building is estimated by measuring the width of the 10-distance to overlapping region. It is measured that the width range of the overlapping region is 4~7 meters, and the mean value is 5.4 meters. The corresponding height can be calculated, and the results are shown in Table 2. Experimental results from the method of this paper and the direct measurement method show that the estimation results of the two methods are much close. Hence we can see that the method of this paper is also applicable to the SAR image of the building.

Table 2. Estimate results of the new method and direct measurement method for measured images

	Length(meter)	Width (meter)	Heigth (meter)
Measurement method in this paper	119.5	51.6	9.4
Direct measurement method	120.1	49.9	10.8

6. Conclusions

As for the defects of low accuracy and practicability of the existing extraction method of building geometric information, this chapter introduces a new framework of building geometric information extraction based on the matching degree of geometric model and image. The framework, on one hand, maps the typical features which contain buildings' geometry information (such as the overlapping and shadow) to the image, on the other hand, the location of the typical features of building image is extracted, and the best model parameters are sought according to the matching degree of the two. The accuracy of the method can be ensured with the introduction of the precise mapping relationship from parameterized geometric model of the building to the image. The practicability can be ensured with the problem of extracting geometrical information transformed into the problem of maximizing the matching degree function, which reduces manpower. And model, typical features of the building, the extraction method and matching degree function can be adjusted in accordance with specific application. Therefore, the new framework combines accuracy, practicality as well as generality.

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Feature Recognition of Body Dance Motion in Sports Dancing

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Abstract
The motion capture of body dance in sports dancing is a process requiring much time and effort, and its recognition cannot be timely achieved, wherein the motion patterns with different types and lengths are connected. Compared with the segmented motion pattern recognition, it faces with another challenge: to detect their boundaries (starting and ending frames) when recognizing each pattern. For this purpose, this paper puts forward two different solutions. One is to use OE-DTW with open ending to find out optimum matching features in complete and incomplete patterns, wherein each input motion sequence is considered as a complete pattern, while each prototype pattern is considered as an incomplete pattern. In this way, the segmentation and recognition of each embedded motion pattern are successively conducted. The other method is to put forward a layered matching method based on punishment by taking advantage of SVD time series relationship obtained sub fragments in SegSVD. As a result, the ending of each embedded pattern can be detected by the top matching situation of the prototype patterns.
Key words: BODY DANCE MOTION, DYNAMIC TIME WARPING, INTEGRATED PATTERN, OPTIMUM MATCHING