A KIND OF FILTERING ALGORITHMS FOR LIDAR INTENSITY IMAGE BASED ON FLATNESS TERRAIN

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ABSTRACT:

To improve the effect of Lidar data, and utilize the intensity information of Lidar data, according to the character of Lidar data, a new fusion mean filtering algorithm based on the flatness degree of terrain is proposed. The algorithm uses a new fusion mean filter which is fused the elevation information of each pixel's neighborhood, to deal with the intensity image. The algorithm and mean filtering algorithm are applied in Lidar data, and their results are compared in different evaluation indexes. The result shows the proposed algorithm has some improvement in keeping the advantage of mean filtering algorithm under the condition of preserving unclear edges of the image.

1. INTRODUCTION

Lidar（light detection and ranging）（flood,2001）is a kind of specific transmitting, scanning, receipting and signal processing technique that use Lidar to recognize target by echo ranging, orienting and getting the position, radial velocity and the character of reflection from object. Lidar is derived from the conventional laser range finding technology of engineering survey, and it is the adjoin product of traditional radar technology and modern laser technology.

As the early data of Lidar is the three dimensional coordinate of target (i.e. the arrange image), the data procession and application of Lidar data mostly focus on the immediate observation and application of distance information. Utilizing a algorithm to classify the Lidar data point to ground point and terrain feature（vegetation, building, vehicle）,then use ground data to create DEM（F.Bahk,2004）or dispose terrain feature, according to different purpose such as vehicle discriminate（A.Rakusz,2004）, building three-dimensional modeling（Hans - Gerd mass,1999）, obtain tree parameter（M.Heurich,2004）,and so on. Because the reliability and accuracy of the classification which is generating DEM and abstracting terrain feature just by virtue of the range information of Lidar data（Zhang Xiaohong,2002）, many scholars have acquired some success by fusion correlative data（aviation image, two - DGIS data, etc.）with Lidar data（Leena Matikainen,2004；M.Heurich,2004）. However, since the acquisition of the Lidar data and fusion data are not synchronous, we must precede pre-treatment such as match and interpolation, which affects the precision of effect. For the moment, advanced Lidar system could record target echo intensity information which is same to the spectroscopic data in nature when it obtain the range information. Since these two kinds of data are acquired at identity time by identity system, they have the condition of fusion in pixel level. In the last few years, it is increased in utilizing the Lidar intensity information. In the turkey annual institute of ISPRS in 2004, there are some successful cases in utilizing Lidar intensity information. Such as: by using the intensity information and arrange information as component vector, Bin Jiang cluster analysis the Lidar data which have gain spatial body. T.Lovas having considered the intensity of each pixel when get vehicle from laser feet point. Simon CLODE use range information generating DEM, then estimate the intensity in each point which is located on the DEM. Those points whose intensity value inside the given interval are alternate points（namely, filtering based on intensity information）, at last using the way of digital image processing abstract the road from the range image. All the approaches mentioned above are complex utilization multi-information of Lidar data, and acquire approving effect. All these processing methods dispose the range image which is translated from the range information by fusing intensity information as the assistant condition. For the moment, all the processing methods to deal with Lidar data are stems from classical digital image processing approaches. Since the classical digital image processing approaches are aimed at the intensity or gradation images, range images which records the distribution of multipoint ranging value in two-dimensional surface, and whose pixel value are ranges, are obviously different to intensity or gradation images. These lead to the treatment effects under anticipation.

In this paper, we research how to utilize the intensity image generated by the laser echoed signal, how to improve the conventional filtration, and how to discuss the feasibility of filtering the intensity image by fusing the range information.

2. LIDAR AND ITS DATA PROCESSING

2.1 The theory of Lidar

Given a point Os whose co-ordinate is（Xs,Ys,Zs）,S is the vector between Os and the point of certainty P（X,Y,Z）which is on the ground, then we can get the co-ordinate of point P by plus Os and S (Liu Shaochuang,1999) .

2.2 The characteristic of Lidar data

Generally speaking, the raw data of Lidar is two-sets interval sampling data : POS（Positioning and Orientation System） data and corresponding instant sweep angle's range measurement value of laser. The three dimensional coordinate of the footprints can be obtained by a train of disposing such as treatment of GPS data attitude determination and system time synchronization, etc. For the moment, advanced Lidar system can record the intensity information of the laser footprint while detect its three-dimensional location. In this way, the data has gray and range information at pixel level at the same time, which is an advantage compared to the conventional remotely-sensed image. To dispose the conventional laser imaging system such as cohere Lidar, acoustics imaging and infrared medicine imaging, the general approach is directly processing the image by utilizing conventional image processing techniques (Sui Liansheng,2003; Jiang Lihui,2003). To restructure or represent the character and structure of the geometric surface in object, the image disposed by these approaches is different geometric surfaces of an object. Since the data gain from Lidar is the character and structure of the heavenward geometric surface of the terrain feature, the method mentioned above is not suitable to Lidar data. So, according to the character of Lidar data, to dispose the Lidar data by fusing the range information and intensity information is a new way in the research.

3. ALGORITHM DESIGN

The intensity information of Lidar is generated from the echoed signal reflected by the object which irradiated by monochromatic wave. It has serious noise, whose essential components are Gaussian noise, impulse noise, speckle noise, etc. Because it is nonlinear, and signal correlative, some multiply noise is hard to remove. To remove noise, we general use mean filtering in digital image processing (Li Ziqin, 2003; Jiang Lihui, 2003). According to the character of Lidar data, this paper presents a new mean filtering algorithm to deal with the intensity image fused range information.

Mean filtering is to substitute each pixel's grey scale value in digital image for its neighboring average values. Assuming $\{x_{ij,}(i,j)\in I^2\}$ is the digital image, filtering window is A ((2k+1) * (2k+1)), the mean filtering is:

$$y_{ij} = \sum_{r,s\in A} x_{(i+r,j+s)} \Big/ (2k+1)^2$$

The window of two-dimension mean filtering can be square, sub-circular or crisscross. Although mean algorithm is simple and its computing speed is fast, it makes image blurring especially in edge and detail. To solve this shortcoming, there are many refinement algorithms, such as hyper pixel smoothness, reciprocal gradient weighting smoothness most uniformity smoothness, part statistic filtering, etc. According to the characteristic and merit of Lidar data, this paper presents a sort of new mean filtering algorithm.

3.1 Theory

The purpose of filtering is to removal the noise in image, at the same time, it cannot destroy the edge of terrain feature so that the sorting process can be benefit. How to separate terrain feature edge and noise is the kernel of different kinds of filtering algorithm. The traditional mean filtering count pixel grey value promiscuously using the mean value of all its environmental pixels, which makes the terrain feature edge be weaken, although it can restrain noise. This is disadvantage to the subsequent sorting process. Consider that different terrain feature has different elevation, when disposes pixel, this algorithm considers its elevation information in the neighborhood. Only the pixels whose elevations most approach the on hand pixel's elevation can their values be used in determining the pixel's values. In this way, we can avoid the disturbance of different terrain feature in neighborhood, which means keeping the marginal information of the terrain feature in hand while restrains the noise. It is obvious that this algorithm can keep more edge and detail information than those traditional mean filtering algorithms.

3.2 Procedure

In this algorithm, we disposes the elevation information in its eight - neighboring region, that is to calculate the elevation flatness in the top left corner sub-neighboring areas, left down corner sub-neighboring areas, top right corner sub-neighboring areas and lower right corner sub-neighboring areas, then takes the mean grey value of the sub-neighboring areas which is the least flatness of the four to be the new value of x_{ij}

Definition, elevation flatness:

$$V = \sum_i \sum_j (f(i,j) - p(i,j))^2$$

Where: $f(i,j)$ is each pixel's elevation in sub- neighboring areas, $p(i,j)$ is the mean elevation in sub- neighboring areas

For example: Calculate the elevation flatness of fellow figure

1	1	1
0	1	1
0	0	0

The top left corner sub-neighboring areas is:

1	1
0	1

The elevation flatness is: V_{tl} = (1-3/4)2+ (1-3/4)2+ (1-3/4)2+ (0-3/4)2=3/4

In a similar way, we can gain the elevation flatness of left down sub- neighboring, top right corner sub- neighboring , lower right corner sub- neighboring : 3/4, 0 and 1. The elevation flatness of top right corner sub- neighboring is 0. Every elevation of top right corner is 1. It is obviously that the top right corner sub-neighboring is the most evenness in the area. So we can know that the more smallness of elevation flatness, the more evenness of terrain. So the algorithm takes the mean grey value of the top right corner sub- neighboring as the new grey value of pixel in hand.

4. TEST RESULT AND COMPARATIVE ANALYSIS

The test converts the intensity information of Lidar data in one region to a 1487 * 1325 * 256 BMP image (Figure 1). It must be indicated that the processing is based on the raw data, and the converting to BMP image is just for the visualized demand.

The resample would bring interpolation error, and the integral in grey quantify and stretch transform would bring option error. All these would lose some precision.

Fig 1 Lidar intensity image

4.1 Result

The follows are the experimental results disposed by 3*3 window, to express clearly, this paper uses a part of image to expresses. Fig 2 is a part of the original image, Fig 3 is the result of mean filtering, and Fig 4 is the result of flatness mean filtering.

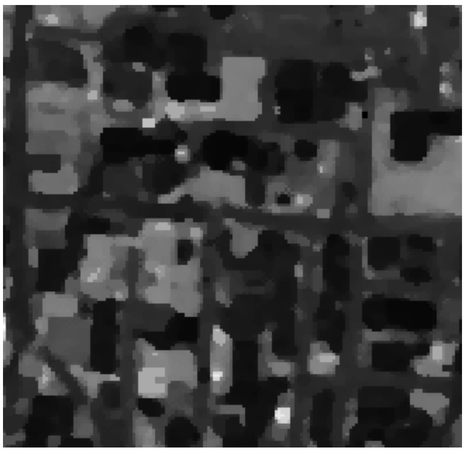

Fig 2 Original image (part)

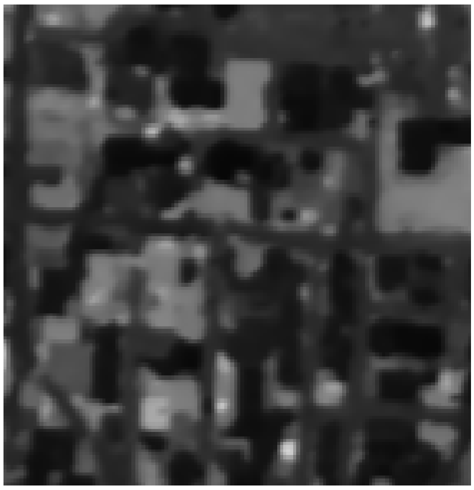

Fig 3 Mean filter (part)

Fig 4 flatness mean filtering (part)

4.2 Result Analyses

To compare the picture quality before and after filtering, this paper introduces several picture quality indices.

4.2.1 Edge stretching: This index is used to evaluate the ability of algorithm in keeping image edge. Judged from the image, due to the average operation, the mean filtering and flatness mean filtering all have stretching in edge and fainting in boundary, which is disadvantage to the edge abstracting in next step. Compared to the mean filtering, the edge stretching of flatness mean filtering is small.

4.2.2 Preserving unclear edges: The index is used to evaluate the protective capability of the unclear edges of object. Compare the images, we will find that the protective capability of the unclear edge point of mean filtering is weaker than that of the flatness mean filtering.

4.2.3 Speckle-index: The index is used to evaluate the inhibiting ability to speckle noise. The smaller the speckle-index is, the better the ability to restrain speckle noise of algorithm.

(1)

$$Speckle-index = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}\frac{\sigma(i,j)}{\mu(i,j)} \quad (1)$$

where M、N is the dimensions of the image, σ (i, j)、μ (i, j) is the standard error and mean of the window.

Algorithm	the mean filtering	the flatness mean filtering
Speckle-index	0.164393	0.128959

Table 1. the Speckle-index

4.2.4 Definition (Xu Hui, 2004): The index is used to evaluate the improvement of image quality, the detail contrast grade in image and transform character of vein. The improvement of definition always characterizes enhance of quality, detail information and texture feature in the image.

$$\overline{G} = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}\sqrt{\Delta xf(i,j)^2 + \Delta yf(i,j)^2} \quad (2)$$

where $\Delta xf(i,j), \Delta yf(i,j)$ are the differences in X, Y direction of $f(i,j)$

Algorithm	the mean filtering	the flatness mean filtering
definition	16.148538	19.467199

Table 2. the definition

5. CONCLUSION

From the indexes mentioned above, we can conclude that judged by the subjective judgment or objective statistical indexes, the flatness mean filtering algorithm, which fuses range and intensity information, has kept the advantage of the traditional mean filtering and improved the protection of the unclear edge object.

It is proven in practice that to classify and identify terrain feature only by Lidar range data can not get satisfactory result. So does in only using Lidar intensity information. Furthermore, the ways mentioned above can not incarnate the superiority of Lidar compared to the traditional remote sensing, and can not display the sophistication of Lidar in full power. It is the aspect of using Lidar in future that bonding the range data and intensity information, and utilizing inherent advantages. This paper just makes a preliminary discussion, further research need keep on.

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