DATA FUSION WITH INTEGRATION OF AIRBORNE LASER SCANNING DATA AND ORTHO-AERIAL PHOTOS

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ABSTRACT:

Two kinds of method, raster fusion and vector fusion, is proposed for fusion operation by integration of LIDAR point cloud and Ortho aerial photos in this paper. The data set used in the paper and data process for preparation is introduced firstly. In order to complement the raster fusion, the points cloud is interpolated into a raster style by Inverse Distance Weighted(IDW) method using Z and Intensity values. Then the IHS transform and Principal components analysis(PCA) algorithms are used to fuse the data information. For vector fusion, the overlay analysis, which is a technology of spatial analysis, is chosen to integrate the spectral information with points. The quantitative analysis about entropy is conducted to evaluate the fusion results. It shows that the PCA fusion is better than IHS transform.

1. INTRODUCTION

1.1 Objective

Airborne laser scanning system (LIDAR) is an advanced active sensing system on acquirement of the ground three-dimensional data. The system emits a controlled laser radiation, independent of solar light, to have the ability to observe the target on the ground day and night. It can obtain the ground three-dimensional data directly, with higher precision, higher efficiency, higher density and lower cost than traditional measuring methods, which is the forefront of photogrammetry and remote sensing area.

Since the 1980s, airborne laser scanning technology had a major breakthrough, Germany, the Netherlands, the United States, Canada, and other related research institutions are paying much attention on laser scanning altimetry and extraction of topographical features. The technologies had been flourishing since the end of the 20th century, gradually expanding the scope of application.

The current airborne laser scanning technology developed rapidly, which has been able to record location information by calculating several times echo and echo intensity information, and provide the same region of digital photos and wave data. On the other hand, compared to the current airborne laser altimeter scanning hardware development, data-processing algorithm has lagged behind. The method depending on the altimeter data to extract feature needs quite improve, especially in the data reliability and accuracy fields. If the integrated image data, multi-spectral data and GIS data can complement each other and make full use of their advantages that is expected to achieve a satisfactory result.

This paper analyses the two expression forms of the LIDAR point cloud, as well as the interpolation of point cloud: based on the integration of grid and based on the integration of vector. Then the point cloud data are integrated with Ortho-photomap, according to Z coordinate values and echo intensity. The process based on grid integration, uses the transform HIS methods and PCA methods. And the process based on vector integration uses GIS Spatial Analysis methods.

1.2 Existing relative works

Fusion of remote sensing images is an advanced image process technology to inosculate the information from different kinds of data sources. The main purpose of this technology is to integrated the different spectral information from certain sensor or different sensors, eliminatethe redundancy and contradictory, reduce the ambiguility, enhance the transparency and improve the accuracy and reliability of image interpretation. Besides, this technology is superior in these fields(LI Jun, ZHOU Yue-Qin and LI DeRen,1999): ①Sharpen image; ②Improve the accuracy of geometric correction; ③Provide the ability of stereo measurement based on photogrammetry; ④Increase the feature information from single data source; ⑤Improve the results of classification; ⑥Change detection from multitemporal data;⑦ Replace the missed information by other data sources; ⑧Overcome the imperfection of objects extraction and reorganization.

Researches for images fusion between remote sensing images have been started for many years. The most traditional methods are IHS transfer(Yang Jin and Liu Jianbo,2007), Principle Component Analysis (PCA)(WANG Wenwu, 2007), High Pass Filter (HPF) and so on. Wavelet fusion is also common used and developed recently. It is mainly focused on the fusion

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between high resolution panchromatic images and high-spectral images(LI Jun, ZHOU Yue-Qin and LI DeRen,1999), spot images and TM images(WANG Zhijun, LI Deren and LI Qingquan,2001), IKONOS images and multi-spectral images(WANG Zhijun, LI Deren and LI Qingquan,2001), QuickBird images(L IU Chun and CHEN Neng, 2004), Sea Ice Remote Sensing Image(WU Kui-qiao, WANG Hu, HUANG Run-heng and LIU Jian-qiang,2005). Besides these technologies, Support Vector Machines(ZHAO Shuhe , FENG Xuezhi , DU Jinkang and LIN Guangfa, 2003)and Genetic Algorithm(TONG Xiao chong, ZHANG Yong sheng and BEN Jin, 2006) are also used for image fusion.

As discussed above, image fusion had been studying for many years. However, rarely research results can be seen focus on fusion between LIDAR points and images.

2. DATA SET AND DATA PROCESS

2.1 Data

The data used in this research represent a region in Yantai, Shandong province of east China and all the data are supplied by North China Sea Branch of SOA. And the data are generated by ALS 40 LIDAR system. There are over 8 flight strips in the original data set. The data acquisition time is about 2.5 hours. Since the huge data volume, two flight strips are selected for research and experiments. The rough latitude is about 37° 35′ 53.74″ and the longitude is about 121° 23′ 06.18″ .

After post process of LIDAR, the total number of points in these two flight strips is about 6,570,000, however the number of Ortho-photomaps is 22. Obviously, the data is still too huge for research. In this paper, the sub-area with the coordinate scale (621290, 416475)-(622666, 4163298) are selected for further data process and fusion research. Thus, the data in this area, including the data points and the Ortho-photomap, are split from the processed data. The area of this region is about 2 km^2. We can also find that there are hills, lakes, sea, buildings, roads in this region. The resolution of this image is 2052*2178 and the pixel resolution is 0.667 m. The number of the points in this region is over 290,000. Fig.1 shows the location and the Ortho-photomaps of this region.

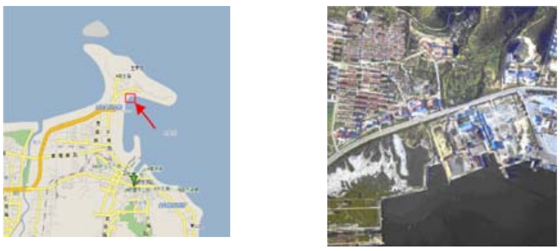

Fig.1 Location and Ortho aerial photo of research area

2.2 Data Component of Points Cloud

The data set from field survey is processed by some software which is supplied by LIDAR systems. With some steps, like post GPS process, interpolation of IMU data, integration of GPS data and IMU data, integration with laser data, instrument and temperature correction, intensity correction, data projection, the data points, which is called Points Cloud, will be gathered in a file. Usually, the points cloud is stored in a las-file. With the help of TerraScan and TerraMoulder, the las-file can be changed into a text file. Thus, the content of points cloud and the main data component of a text file is listed as below：

$$Coordinate\_X, Coordinate\_Y, Coordinate\_Z, Intensity$$

Here, $Coordinate\_X, Coordinate\_Y, Coordinate\_Z$ indicates the geometry of a certain point, while $Intensity$ indicates the optical information of each echo.

The coordinate system used here is the Guass-projection with WGS84 global reference. During the data process, the same coordinate system is adopted in both points cloud and Ortho-photomaps. So the reference of these two data set are nearly the same. Since there’s no public ground control points(GCPs) between images and points, the matching between two data set is not conducted. If there’s enough GCPs, the matching is needed for experiment.

The following Figure 2 shows the points used in this paper.

Fig.2 Points Cloud(298,699 points)

2.3 Interpolation of Points Cloud

Points cloud gives the coordinates and optical information in vector format, while the Ortho-photomaps gives the spectral and geometric information in raster format. Traditionally, there’s no direct method for data integration between vector data and raster data. In order to integrate the information of points cloud and that of raster images, two methods can be used to achieve the purpose. The first one is to interpolate the points cloud in vector format into raster format. Then some useful fusion approaches, such as IHS transform and PCA, are selected to integrate the two data. The second method is to integrate every point in points cloud with raster pixel according to the coordinate relationship. Obviously, the result by first method is a raster file and it covers the whole area. The result by second method is a vector file and the volume of result data is the same with original points cloud. But it may not cover the whole area. In this paper, the two methods are both used to implement the fusion process.

As introduced above, in order to conduct the fusion of points cloud and images, the points should be interpolate into raster format firstly. Interpolating can be regarded as resample. Some approaches, such as Inverse Distance Weighted(IDW), Spline, Kriging can be used here. In this paper, we use Inverse Distance Weighted method to interpolate the vector points into raster.

As mentioned in section 2.2, Z coordinate and the intensity are included in points data. Both of the two data reflects the objects information. So, during the interpolation, Z and the Intensity values are used as the key value. Fig.3 and Fig.4 indicates the results of interpolation by Z and intensity values.

Fig.3 Raster Image by Interpolation of Z

Fig.4 Raster Image by Interpolation of Intensity

Since some uncertainly factors and different spectral characteristic during the data acquisition, the intensity values is not as normal as Z values. Even in the same building, the intensity will change violently. Thus, Fig.3 is more smoothness and flatness than Fig.4. The buildings and the hills which are higher than the terrain is quite obvious in Fig.3 but the buildings can not be recognized in Fig.4. However, the road and the plants is clear and vivid compared with the Fig.3.

3. DATA FUSION

3.1 Raster Fusion between image and points cloud

IHS fusion

The IHS colour space is broken down into Hue, Saturation and Intensity. In order to separate the intensity from IHS colour space from the intensity value of points, we use I to denote the intensity value of IHS colour space and $Intensity$ to denote the intensity value of points cloud. Hue refers to pure colour, saturation refers to the degree or colour contrast, and intensity refers to colour brightness. Modeled on how human beings perceive colour, this colour space is considered more intuitive than RGB. It can be compared to the dials on an old television set that help viewers adjust the set's colour.

To analyze and process images in colour, machine vision systems typically use data from either the RGB or HSI colour spaces, depending on a given task's complexity. For example, in simple applications such as verifying that a red LED on a mobile phone is indeed red and not green, a vision system can use data from R, G and B signals to perform the operation. With more complex applications, however, such as sorting pharmaceutical tablets of subtly different colours, a vision system may require hue, saturation and intensity information to perform the operation.

IHS fusion is based on the conversion between IHS colour space and RGB colour space. It is useful on the fusion between multi-spectral images and the panchromatic images. During the IHS fusion process, the RGB values of multi-spectral image should be converted to IHS values for each pixel. Since there's only grey value in panchromatic images, the grey value is considered as the RGB values. So, the panchromatic images can also be converted to IHS colour space. Then the I values of multi-spectral image can be used for further process by some other image such as panchromatic images. Fusion image can be get after the inverse transform of IHS colour space to RGB.

The first fusion experiment is executed between Ortho-photomap and results of interpolation of Z value. Here, the I values of Ortho-photomap are replaced by the grey value of interpolation results. Fig.5 shows the result of the first experiment.

The second experiment is executed for Ortho-photomap and results by $Intensity$ value interpolation. Here, the I values of Ortho-photomap are replaced by the grey value of interpolation results. Fig.6 shows the result of the second experiment.

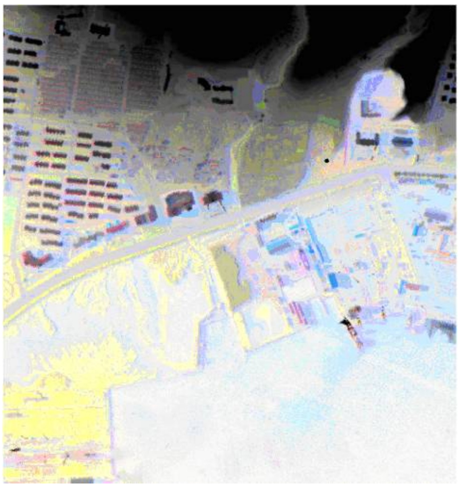

Fig.5 IHS Transform Fusion Image based on Fig.1 and Fig.3

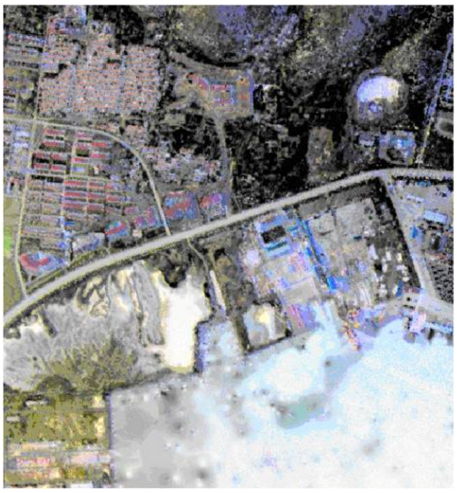

Fig.6 IHS Transform Fusion Image based on Fig.1 and Fig.4

Principal Components Analysis (PCA) Fusion

Principal components analysis is a method in which original data is transformed into a new set of data which may better capture the essential information. Often some variables are highly correlated such that the information contained in one variable is largely a duplication of the information contained in another variable. Instead of throwing away the redundant data principal components analysis condenses the information in inter-correlated variables into a few variables, called principal components. Principal components analysis is a special case of transforming the original data into a new coordinate system. If the original data involves n different variables then each observation may be considered a point in an n-dimensional vector space. The change of coordinate system for a two dimensional space is shown below.

Principal component analysis is a method that integrates multi-variables into few variable. In terms of mathematic, it belongs to the technology of dimensional reduction.

Assume the original data is given in the form of z_{ij} where the index i stands for the variable number and j for the observation number. In some conditions, the total variable number is quite numerous and it's not convenient for researcher to deal with the problem. In this condition, less but integrated variables are used to replace the original variables. For the integrated variables, the most information of the original variables should be reflected.

During the fusion between LIDAR points and Ortho-photomaps, there're over 3 variables to indicate the pixel information including $Coordinate\_Z$, $Intensity$, R , G , B information. So the PCA algorithm can be used to built new variables for dimension reduction.

Here, we consider R, G, B, Z and Intensity values as the original components. Since the resolution of image is quite huge, 1,000 pixels are selected as sample points to conduct the PCA. The eigenvalue and the contribution ratio is listed in the following table.

index	Eigenvalues	Contribution Ratio	Cumulated Contribution Ratio
1	3.5693	71.39%	71.39%
2	1.0764	21.53%	92.92%
3	0.2941	5.88%	98.80%
4	0.0522	1.04%	99.84%
5	0.0080	0.16%	100%

Table.1 Eigenvalues and Contribution Ratio

We use L to denote principal components load matrix which can also be get from PCA process. In this experiment, $L=$

$$\begin{matrix} 0.9372 & 0.9495 & 0.9446 & 0.6146 & 0.7207 \\ 0.3198 & 0.2974 & 0.2711 & -0.7035 & -0.5632 \\ 0.0350 & 0.0480 & -0.0070 & 0.3569 & -0.4039 \\ -0.1233 & -0.0529 & 0.1842 & 0.0051 & -0.0157 \\ 0.0539 & -0.0695 & 0.0159 & 0.0026 & -0.0016 \end{matrix}$$

Usually, we choose Eigenvalues that it's corresponding cumulative contribution ratio is above 95% as new principal components. In this condition, new principal components, $R1$, $G1$, $B1$, are built as follows:

$$\begin{cases} R1 = 0.9372\times R + 0.3198\times G + 0.0350\times B - 0.1233\times Z + 0.0539\times Intensity \\ G1 = 0.9495\times R + 0.2974\times G + 0.0480\times B - 0.0529\times Z - 0.0695\times Intensity \\ B1 = 0.9446\times R + 0.2711\times G - 0.0070\times B + 0.1842\times Z + 0.0159\times Intensity \end{cases} \quad (1)$$

Use the $R1$, $G1$, $B1$ as the new RGB values of the fusion image. The fusion result are shown as the Fig.7.

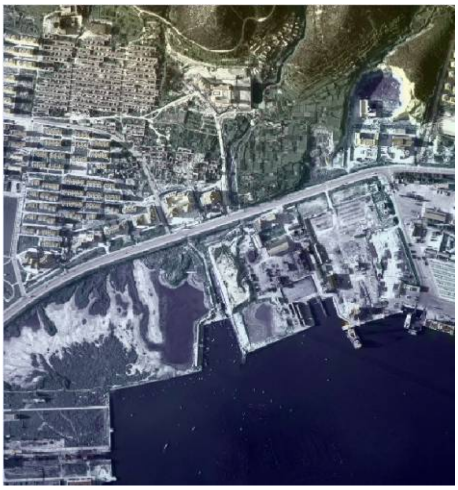

Fig.7 Fusion Image By PCA

Quantitative Analysis

Entropy analysis is chosen for quantitative analysis in this study. In terns of Shannon principle, the entropy can be calculated by equation(2)

$$H = -\sum p_i \times \log_2 p_i \tag{2}$$

The entropies of original data and the fusion images are calculated and listed in the following table.

image		entropy	image		entropy
Fig.1	R	7.5164	Fig.6	R	6.5786
	G	7.5169		G	6.3843
	B	7.4070		B	7.0040
Fig.3		5.6076	Fig.7	R	7.7382
Fig.4		4.6589		G	7.8019
Fig.5	R	6.1682		B	7.6527
	G	5.9279			
	B	6.3698			

Table.2 Entropy Contrast Table

In Table.2, the entropy values of Fig.1, Fig.2, Fig.3 shows the information contained in the corresponding images or band before fusion. Fig.5, Fig.6, Fig.7 represent the fusion images by IHS transform and PCA. The entropies are listed in Table.2. It is quite obvious that the entropy values of Fig.5 and Fig.6 is lower than Fig.1, but higher than Fig.3 and Fig.4. It means the spectral information in Fig.5 and Fig.6 is lost during the fusion process from Fig.1. Of course, after fusion, the information content have been increased from Fig.3 and Fig.4.

The entropy value of Fig.7 is higher than that of Fig.1, Fig.2 and Fig.3. It means that information in Fig.7 is more abundant than this images. Also, the entropy values are higher than that of Fig.5 and Fig.6. It indicates that the fusion result by PCA is better than result by IHS transform.

3.2 Vector Fusion between LIDAR points and images

Fusion discussed in section 3.1 indicates that fusion between raster points and Ortho-photomap. The information in these two data sources are complemented by each other. It is also clear that some of the spectral information is lost during the fusion procedure. Since the data source are all in raster format, this technology is also called raster fusion.

Here we use vector Fusion to denote the fusion process between LIDAR points and images. When conducting the fusion, the LIDAR points are in vector format. This technology is used for appending the spectral information to every points according to the location relationship. It also means that not only coordinate data but also spectral and optical information are included in results.

Since the coordinate relationship between points and images, the spatial analysis tech can be used for vector fusion. The most useful method for fusion is overlay analysis. For each LIDAR point, the corresponding pixel which lies in the same coordinate with the point is selected firstly. Then the spectral data, usually in R, G and B, are acquired and attached in the point. So, the data components of fused vector points are here listed:

$Coordinate\_X, Coordinate\_Y, Coordinate\_Z, Intensity$

The forth experiment is executed for Ortho-photomap and vector image of points cloud. Here, the I values of Ortho-photomap are replaced by the grey value of interpolation results. Fig.5 shows the result of the first experiment.

Fig.8 Fusion Image by Overlay Analysis Method

4. CONCLUSION

Two kinds of method is executed for fusion between airborne laser scanning points and Ortho-photomap, raster fusion and vector fusion. In the part of raster fusion, the IHS transform and PCA algorithm are used for the integration of points data which have been interpolated into raster and raster image data. While in the part of vector fusion, the overlay analysis technology, which is a part of spatial analysis, is used to complete the integration of points and image. In terms of fusion images, both of the methods is helpful. But from quantitative analysis, the result from IHS transform is not as good as PCA. At the same time, the entropies shows that the result from IHS transform have lost some information from the original data. But the result from PCA shows that the information is increased. PCA is better than IHS transform in fusion between LIDAR points and Ortho-photomap.

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