BUILDING DETECTION BY DEMPSTER-SHAFER METHOD USING MULTI-VIEW IMAGES

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ABSTRACT: Building detection is important in updating GIS data layers. The major information contents in building detection are shape and spectrum when images are employed. Multiple image matching may generate 3D point clouds to form the 3D shape outline. Thus, we can obtain normalize digital surface model (nDSM) by excluding digital elevation model (DEM). On the other hand, multi-spectral images provide color information for building detection. The Normalized Difference Vegetation Index (NDVI) can separate vegetation from buildings. Besides, considering the building characteristic, we define a weighted matrix based on the building lines. We assume that around each building line there is a high possibility of building areas. Final, we employ the Dempster_Shafer method to perform classification of different data based on the evidence that each feature provides for each class hypotheses. Hence, these three features (nDSM, NDVI, weight) are used by Dempster-Shafer to detect buildings.

The proposed method comprises six major steps: (1) determination of building lines, (2) multiple image matching, (3) generation of nDSM, (4) spectrum analysis, (5) weighted matrix formation, and (6) Dempster-Shafer classification. Extracting features by Canny operator and deciding the building lines by Hough transform from the reference image is the first step. Second, geometrically constrained cross-correlation algorithm and Central-Left-Right matching are selected in the multiple image matching to generate 3D point clouds. Third, the nDSM is derived by excluding terrain evaluation. Fourth, NDVI is obtained by spectrum analysis. Fifth, we form a weighted matrix based on the building lines. Finally, we use these three features (nDSM, NDVI, weight) to detect buildings by using Dempster-Shafer method.

The test datasets include six aerial images with 9cm spatial resolution and the overlap and sidelap are both 60%. The experimental results show that this research has the high ability to locate building areas.

1. INTRODUCTION

Three-dimensional building models are the important part in geospatial information applications. Before reconstructing the building models, building detection is a necessary work (Rottensteiner & Briese, 2002). There are many mediums to detect the buildings, such as using structural, contextual, and spectral information (Jin et al., 2005). Both, Images and LIDAR data are the common materials. Aerial or satellite images provide fruitful image details and LIDAR point clouds provide highly accurate information of elevation (Huang, 2010). However, aerial images are getting easier to obtain together with high spatial resolution and multi-spectral information. Thus, high spatial resolution aerial images are selected in this study.

Dempster-Shafer (DS) method can be used in classification, when training data is limited (Khoshelham et al., 2010). For Dempster-Shafer method, we use these three features (nDSM, NDVI, weight) to detect buildings. Multiple image matching generate 3D point clouds and form the digital surface model (DSM). The nDSM is generated by excluding terrain elevation from DSM. For the reason, the accuracy of nDSM is related the 3D point clouds. Therefore, how to make image matching valuable is an important work. Image matching usually can divide into two parts. One is feature-based matching (FBM), and the other is area-based matching (ABM). Area-based matching uses the change of gray values to fine the conjugate points and may obtain accurate results. This paper employs the concept of geometrically constrained cross-correlation (GC^3) method, as proposed by Zhang & Gruen (2006), in matching satellite images. If multi-strip images are available, the epipolar lines may be constructed at the different directions and the matching results may be more accurate (Huang, 2010). However, some features may cause ambiguous results in the area with elevation discontinuity. This is obvious in the building areas. Therefore, Hsu (1990) proposed Central-Left-Right matching (CLR matching) to improve image matching when the feature is around elevation discontinuity. Before using Central-Left-Right matching, we need to know the building bearings. Thus, determination of building lines to find building bearings is the first work in this study. The NDVI can separate vegetation from buildings. We use multi-spectral images which provided color information for building detection. Besides, we assume that around each building line there is a high possibility of building areas, so we define a weighted matrix based on the building lines.

2. METHODOLOGIES

The proposed method comprises six major steps: (1) determination of building lines, (2) multiple image matching, (3) generation of nDSM, (4) spectrum analysis, (5) weighted matrix formation, and (6) Dempster-Shafer classification. The workflow is shown in Figure 1.

2.1 Determination of Building Lines

Considering the building characteristic, we employ Canny (1986) edge detection to detect the feature lines. We assume that most of feature lines are building lines, but there still some others lines be detected. Besides, all the building bearings will not with the same bearing. Thus, we need to separate not only the unwanted feature lines, but also the directions of buildings. In this study, Hough transform (Hough, 1959) is selected for dividing the building bearings from feature lines. After the feature points of the feature lines transform to the Hough space, the building bearings decided by two criteria. One is that the largest peak in Hough space need to larger than the feature points which are transformed, another is that the angle range between largest peak and second-largest peak.

2.2 Multiple Image Matching

According to the different building bearings and corresponding building lines, we purpose the multiple image matching to find the conjugate points in different building bearings, respectively. This method includes multi-window matching and multi-strips image matching. We employ the concept of GC³ method into multi-strips image matching, and use CLR matching strategy for multi-window matching.

2.3 Generation of nDSM

After multiple image matching for generation of 3D point clouds, we use bilinear interpolation to generate the DSM. Considering the building is higher than 3m in general, so we exclude the areas from nDSM where its height is less than 3m.

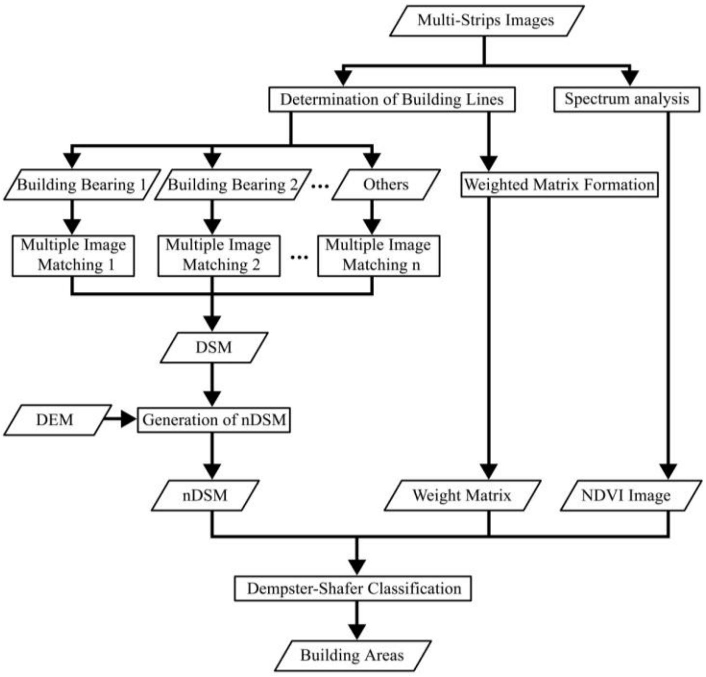


Figure 1. Workflow of the proposed scheme

2.4 Spectrum Analysis

In this study, we employ NDVI to separate vegetation from buildings. Its principle is that vegetation absorbs red-spectral (R) and reflects near infra red (NIR). After calculating the NDVI value, we can generate the NDVI image. The count is shown in equation (1).

$$\mathbf{NDVI = (NIR\text{-}R) \ / \ (NIR+R)} \quad (1)$$

2.5 Weighted Matrix Formation

For this step, we assume that around each building line there is a high possibility of building areas. We define the pixel on the building lines have the highest weighted value 100%, and the pixel, which distance from building lines more than 70 pixels (about the distance between building to building), weighted value is 0%. Basis on that, the weighted matrix is formed by inverse distance to power.

2.6 Dempster-Shafer Classification

For Dempster-Shafer method, we use these three features (nDSM, NDVI, weight) to detect buildings. The Dempster-Shafer classification performs the data into different classes on the basis of the evidence that each feature provides for each class hypotheses (Gordon & Shortliffe, 1990). Instead of a single value, the probability of a class hypothesis is specified with two values: belief and plausibility (Khoshelham et al., 2010). After calculating the belief and plausibility value, each pixel will be classified by considering the highest value from belief or plausibility.

3. EXPERIMENT RESULTS AND ANALYSES

This test site locates in Taipei City of Taiwan. The datasets include six Digital Mapping Camera II (DMC II) images with 9cm spatial resolution, as shown in Figure 2. The overlap and sidelap are both 60%. The image with the smallest relief displacement is chosen as the master image. As shown in Figure 2, the first image is selected as the master images, and others are slave images.

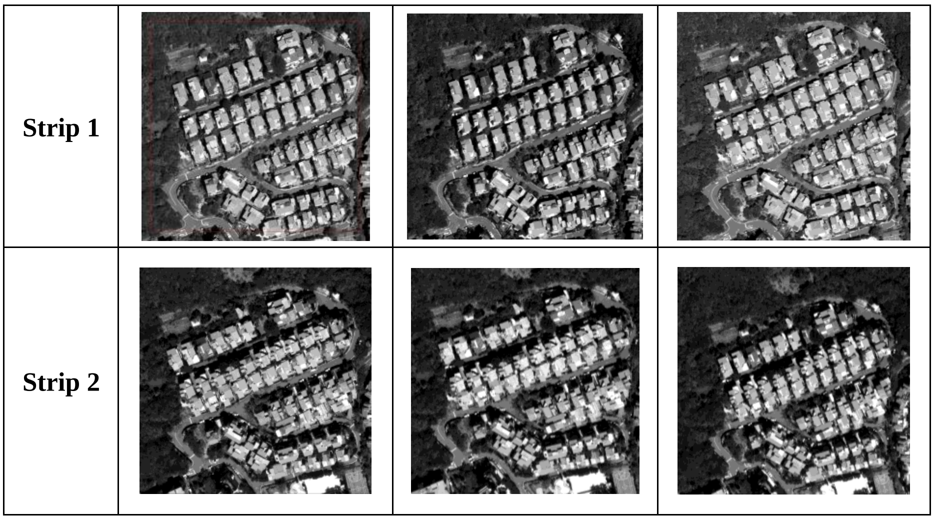


Figure 2. Overlapped images of test example

3.1 Results of Building Lines Determination

First of all, we extract the feature lines only in the master image. There are 83978 feature points on the feature lines, as shown in Figure 3. After the feature points transform to the Hough space, we determine the building bearings by two criterions. The direction of building and number of corresponding feature points are shown in Table 1. In this test area, there are two different building bearings, and the others feature points which did not have building bearing we define their direction is 0˚-90˚.

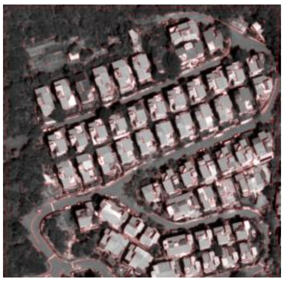
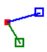
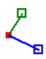


Figure 3. Feature distribution

Table 1. Results of building lines determination

	Building Bearing 1	**Building Bearing 2**	**Others**
Hough Space			
Direction of Building			
Number of Feature Points	71093	12154	731

3.2 Results of Multiple Image Matching

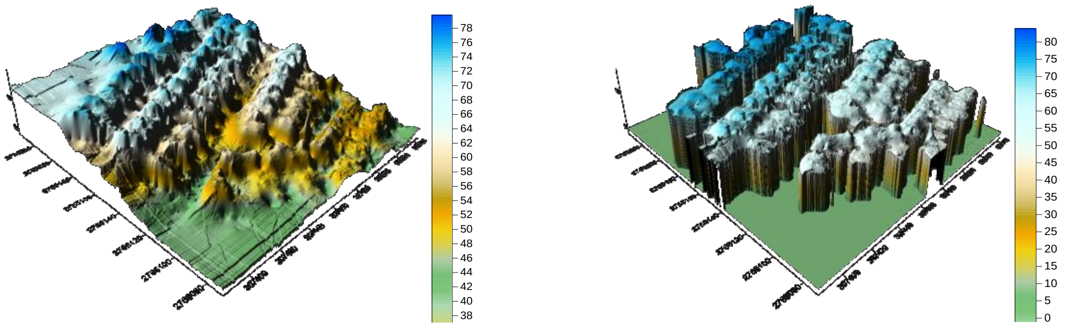
According to the different building bearings and corresponding building lines, we did the multiple image matching in different building bearings, respectively. The result of multiple image matching as shown in Table 2. In this case, the area with building bearings have high successful rate, more than 70%. On the other hand, the successful rate of others points are only 18.194%.

Table 2. Results of multiple image matching

	Building Bearing 1	**Building Bearing 2**	**Others**	**Total**
Number of Feature Points	71093	12154	731	83978
Number of Successful points (R > 0.75)	50514	8562	133	59209
Successful Rate	71.053%	70.446%	18.194%	70.505%

3.3 Results of DSM and nDSM Generation

For this step, we select the minimum normalized correlation coefficient (NCC) threshold as 0.75 to generate DSM by using bilinear interpolation from 3D point clouds. After that, the nDSM is derived by excluding terrain evaluation from DEM. Considering the building is higher than 3m in general, so we exclude the areas from nDSM where its height is less than 3m. The results show in Figure 4.



(a) (b)

Figure 4. Results of DSM and nDSM Generation
(a) DSM
(b) DSM excludes the areas from nDSM where its height is less than 3m

3.4 Result of Spectrum Analysis

In this study, we use NDVI image to be one of the feature for Dempster-Shafer Classification. The test data are an NIR-band image and an R-band image, as shown in Figure 5(a) and Figure 5 (b). Because the NDVI value are between -1 to1, we done a linear transformation to transform they to 0 to 255, as shown in Figure 5(c).

(a) (b) (c)

Figure 5. Result of Spectrum Analysis
(a) NIR-band image
(b) R-band image
(c) NDVI image

3.5 Result of Weighted Matrix Formation

Because we assume that around each building line there is a high possibility of building areas, weighted matrix is formed by inverse distance to power basis on the building lines. However, the weighted value are between 0 to100, so we done a linear transformation to transform they to 0 to 255, as shown in Figure 6.

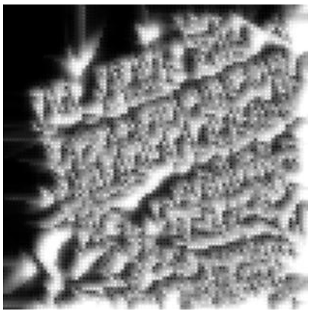


Figure 6. Weighted matrix

3.6 Result of Dempster-Shafer Classification and analyses

There are three features (nDSM, NDVI, weight) used by Dempster-Shafer to detect buildings. Calculating the belief and plausibility value, each pixel will be classified by considering the highest value from belief or plausibility. Here, the nDSM need to back project to the image and use the evaluation become the gray value. Thus, we combine three features (nDSM, NDVI, weight) to a RGB image (R- NDVI, G- weight, B- nDSM), and employ this false-color image to do the Dempster-Shafer classification with training samples superimposed, as shown in Figure 7.

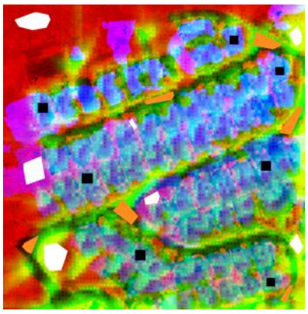


Figure 7. False-color image with training samples

Figure 8. Classified image by Dempster-Shafer mothod

The training samples we select from the image are 3 classes (building, road, and tree). The result of Dempster-Shafer classification has 4 classes including unclassified pixels. Because building detection is the major object of this paper, we join the road, tree, and unclassified pixels into one class, as shown in Figure 8.

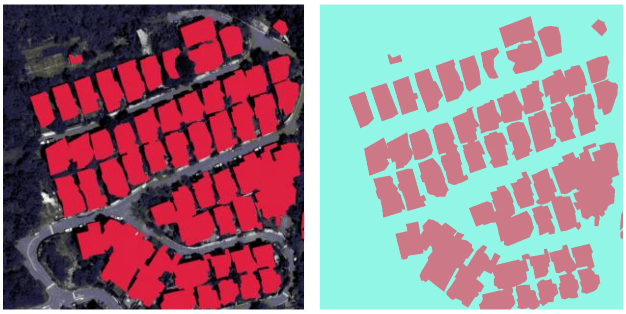


Figure 9. Reference image by manually

For result of classification, we employ a reference image by manually extracted buildings from the image and separate it into two classes (not building and building), as shown in Figure 9. We compare the reference image and classified image by using an evaluation matrix, as shown in Table 3. As shown in Table 3, the Class 1, Class 2, Truth 1 and Truth 2 mean the not building pixel and building pixel from classified image and reference image, respectively. For analyzing algorithm, this paper performs some evaluation metrics including Overall Accuracy (OA), Producer Accuracy (PA), User Accuracy (UA), and Kappa Coefficient. The results of evaluations are shown in Table 4. The OA, PA, and UA are higher than 80%, and the Kappa value is about 66%.

Table 3. Evaluation matrix (pixel)

	Class 1 (not building)	**Class 2 (building)**	**Total**
Truth 1 (not building)	**1666229**	198309	1864538
Truth 2 (building)	288873	**909088**	1197961
Total	1955102	1107397	**2575317** / 3062499

Table 4. Evaluation metrics

	Class 1 (not building)	**Class 2 (building)**	**Total**
OA			0.84
PA	0.89	0.76	0.82
UA	0.85	0.82	0.83
Kappa	0.71	0.62	0.66

4. CONCLUSIONS AND FUTURE WORKS

This paper has proposed a scheme to use highly overlapped multi-spectral aerial images in building detection by Dempster-Shafer mothod. We use these three features (nDSM, NDVI, weight) to detect buildings. For multiple image matching, the area with building bearings have high successful rate. It can improves the accuracy on nDSM. NDVI is obtained by spectrum analysis, and it can separate vegetation from buildings. The weighted matrix is formed by inverse distance to power basis on the building lines. We combine these three features to employ the Dempster-Shafer classification. The final results show that this research has the ability to locate building areas. The Accuracy of classified image is better than 80%, and the Kappa value is about 66%. Since the characteristics of different features are different, we will try to use different weighting for them in the future.

5. ACKNOWLEDGMENT

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