Comparison of Normalized Cross Correlation and Mutual Information for Feature Line Matching

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ABSTRACT

In the feature line matching, a matching index is needed to assess the similarity of neighborhood for feature lines among images. Two common matching indices, Normalized Cross Correlation (NCC) and Mutual Information (MI), are investigated in this study. Considering that the brightness of the image may vary due to lighting and exposure conditions, NCC evaluate the similarity via calculating the cross correlation with normalization between images. On the other hand, MI is a measure of the images' mutual dependence by computing the entropy. The purpose of this study is to match feature lines with these two indices, and their utility for line matching would be discussed.

The matching method in this study includes three steps: (1) extraction of straight lines, (2) selection of interest and candidate lines, and (3) similarity assessment. First, the edges are detected first followed by the extraction of the line feature. After the extraction, the selection of interest lines and candidate lines are implemented on master and slave images, respectively. Thus, the strategy that compares the similarity of line neighboring regions is employed for line matching. In order to compare with NCC, MI is to be normalized. In such a case, the preliminary experimental results show that Normalized Cross Correlation is better performed in line matching than using Normalized Mutual Information.

1. INTRODUCTION

Reliable line matching is beneficial to building reconstruction, because the most objects are mainly composed of line segments along boundaries. Matching for those line segments is a challenge work due to the reasons such as the different line endpoints, repetitive patters, occlusions, etc [Ok et al., 2010]. Features that located at building boundaries may cause matching unreliable, because the neighbor region of the feature may cover the different background in different angle images. Thus, a matching strategy called Left-Right Line Matching (LR Line Matching) is employed in this study. The method compares the similarity with put the line features on the left and right side of the matching window, respectively.

Two common matching indices, Normalized Cross Correlation (NCC) and Mutual Information (MI), are compared respectively in this study. Considering that the brightness of the image may vary due to lighting and exposure conditions, NCC evaluate the similarity via calculating the cross correlation with normalization between images. The value of NCC is between -1 and 1. The larger value of NCC, the more similar between line features. On the other hand, MI is a measure of the images' mutual dependence by computing the entropy. The domain of MI for image matching depends on probability of grey value between matching windows. In order to compare with the NCC, the normalized mutual information (NMI) [Pluim, et al., 2003] is investigated in this study. The value of NMI is always between 0 and 1. The larger value of NMI, the more similar between line features.

2. METHODOLOGY

The matching method in this study includes three steps: (1) extraction of straight lines, (2) selection of interest and candidate lines, and (3) similarity assessment. Since the target in this study is straight line, we use Canny detector first followed by Hough transform for the extraction of straight line in the first step.

After the extraction of features lines with directions, we choose those directions that most lines are agree with. Those lines can be selected as the interest features on the master image. Based on the known exterior orientation parameters, the epipolar geometry is built among the images. Thus, the search region on the slave images can be reduced [Zhang, C., Baltsavias, E.P., 2000]. In the search area, the features with the similar direction to interest line are treated as candidates.

The strategy that compares the similarity of line neighboring regions is proposed in the matching procedure. The matching window size is M*N. M represents the number of pixels along the interest line. N means the half number of

pixels across the line. Two matching indices for similarity assessment, Normalized Cross Correlation (NCC) and Mutual Information (MI) are used respectively in this study.

2.1 Normalized Cross Correlation

Normalized Cross Correlation evaluates the similarity via calculating the cross correlation with normalization between images. The equation of NCC is shown in **Equation (1)**.

$$NCC = \frac{\sum\sum\left(G_I - \bar{G}_I\right)\left(G_C - \bar{G}_C\right)}{\sqrt{\sum\sum\left(G_I - \bar{G}_I\right)^2}\sqrt{\left(G_C - \bar{G}_C\right)^2}} \qquad \textbf{Equation (1)}$$

Where, G_I means the grey value in the matching window of interest line,
$\bar{G}_I$ means the average grey value of the matching window of the interest line,
G_C means the grey value in the matching window of candidate line,
$\bar{G}_C$ means the average grey value of the matching window of the candidate line

2.2 Mutual Information

Mutual Information is a measure of the images' mutual dependence by computing the entropy, the equation of entropy is shown in **Equation (2)** to **Equation (4)**. After the calculation of entropy, a formula for normalized the MI value which shown in **Equation (5)** is employed.

$$H(I) = \sum_i -P_I(i)\log(P_I(i)) \qquad \textbf{Equation (2)}$$

$$H(C) = \sum_c -P_C(c)\log(P_C(c)) \qquad \textbf{Equation (3)}$$

$$H(I,C) = \sum_{i,c} -P_{I,C}(i,c)\log(P_{I,C}(i,c)) \qquad \textbf{Equation (4)}$$

$$\text{Normalized MI} = \frac{1}{2}\left(\frac{H(I)+H(C)}{H(I,C)}\right) \qquad \textbf{Equation (5)}$$

Where, $P_I(i)$ means the probability of grey value in the matching window of interest line,
$P_C(c)$ means the probability of grey value in the matching window of candidate line,
$P_{I,C}(i, c)$means the probability of the different combination of grey value between the matching window of interest line and candidate line,
$H(I)$,$H(C)$ means the entropy,
$H(I, C)$ means the joint entropy.

3. EXPERIMENTAL RESULTS

Test data sets were obtained from DMC II images, the camera information is shown in Table 1. Figure 1 shows the target building in the master image, and 71 lines are selected as interest lines that shown in Figure 2.

Table 1. Camera information

Camera	DMC II
Focal Length	91.9817 mm
Row/Column	12096 x 11200 pixels
Ground Resolution	0.1 m
Image Size	87.091 mm x 80.640 mm
Pixel Size	7.2 μm x 7.2 μm

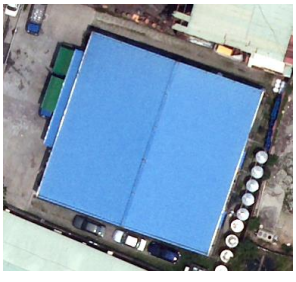

Figure 1. Target building in master image.

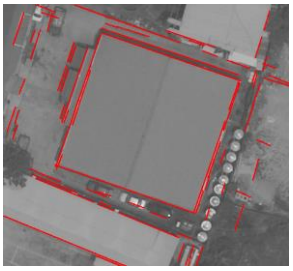

Figure 2. Interest lines.

For an interest line, if it matches to one of the candidate the matching is considered to be successful. An index threshold is to be selected to determine if the candidate line is matched. In this study, we set a number of thresholds to test NCC and NMI. In addition, both indices are also tested with different window size (N). Table 2 and Table 3 show the matching result using NCC and NMI, respectively. It is observed that the feature line matching with Normalized Cross Correlation performed better than using Normalized Mutual Information.

Table 2. Matching results using Normalized Cross Correlation

Index Threshold	**0.5**		**0.6**		**0.7**		**0.8**	
Window Size	**Success Rate (%)**	**Correct Rate (%)**	**Success Rate (%)**	**Correct Rate (%)**	**Success Rate (%)**	**Correct Rate (%)**	**Success Rate (%)**	**Correct Rate (%)**
N = 13	93.0	80.7	90.1	88.3	83.1	93.6	76.1	98.7
N = 15	93.0	82.8	93.0	90.6	84.5	94.6	76.1	98.7
N = 17	93.0	87.2	93.0	92.5	84.5	95.4	74.6	99.3

*N: The half number of pixels across the line.

Table 3. Matching result using Normalized Mutual Information.

Index Threshold	**0.5**		**0.6**		**0.7**		**0.8**	
Window Size	**Success Rate (%)**	**Correct Rate (%)**	**Success Rate (%)**	**Correct Rate (%)**	**Success Rate (%)**	**Correct Rate (%)**	**Success Rate (%)**	**Correct Rate (%)**
N = 13	100.0	51.2	100.0	57.4	38.0	56.9	5.6	76.9
N = 15	100.0	48.5	98.6	55.6	33.8	54.0	2.8	83.3
N = 17	100.0	49.5	98.6	56.2	23.9	47.7	2.8	100.0

*N: The half number of pixels across the line.

4. CONCLUSIONS

This paper compares two matching indices for feature line matching. In order to compare with Normalized Cross Correlation, Mutual Information needed to be normalized. In such a case, the preliminary experimental results show that Normalized Cross Correlation is better performed in line matching than using Normalized Mutual Information. The success rate and correct rate could reach 90% and 80%, respectively.

5. ACKNOWLEDGEMENTS

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