The extraction of lineaments from satellite images in Phayao-fault zone

N Sukphornsawan¹, C Suwanprasit¹ and P Wongpornchai²

¹Department of Geography, Faculty of Social Sciences, Chiang Mai University, Chiang Mai 50200, Thailand
²Department of Geological Sciences, Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand

Corresponding author’s email: nuttothai004@gmail.com

Abstract. Lineament mapping is an important part of structural geological investigation that are important features showing subsurface elements or structural weakness, such as geological faults. Most of lineament features are normally extracted by visual interpretation of enhanced image data. The main objective of this work was to develop a method for semi-automatically extracting lineament using remote sensing data. Landsat 8 OLI original image (excluded band 1, 8, 10 and 11) of Phayao-fault zone was operated. There were three main steps in the study including 1) improve quality of dataset using Principal Component Analysis (PCA), 2) delineate lines from the result of quality improvement and 3) classify lineament using visual interpretation. The results from PCA – Band 3 showed the most correlated when compared with existing data. The extracted lineaments were correlated to geological lineament, stream and road network about 42.46 %, 20.52 % and 7.22 % respectively.

Keywords: Lineament, Landsat, Principle component analysis, PCA, Phayao-fault zone

1. Introduction
Lineaments mapping plays a main role in geological studies [1]. In addition, they may relate to natural objects, such as a structural alignment, geomorphologic consequences, structural weaknesses, faults, valleys, drainage areas, fractures or lines separating the different formations [1]. Lineaments can be detected due to their physiographic features that caused the tonal change in contrast to the relief, pattern and textures in the satellite images [2]. Currently, the remote sensing discipline allows exploiting a variety of sources and methods in the characterization of lineaments. Therefore, remote sensing data have been widely used in lineaments mapping [1, 3-5]. The main objective of this work was to develop a method for semi-automatically lineament extraction using remote sensing techniques and Landsat 8 OLI imageries.

2. Study area
The study area is located in between 4 provinces of northern region of Thailand including Chiang Mai, Chiang Rai, Lampang and Phayao which is between longitudes 99º 00'/E to 100º 20'/E and latitudes 18º 00'/N to 20º 00'/N, within area approximately 12,204.1 km² as shown in figure 1.
There are many earth line characteristics in the study area that suit appropriately to develop method for the lineaments extraction.

3. Data and methodology

3.1. Data
Landsat 8 OLI images used in this study corresponded to 15 and 22 February 2016, at the L1T (corrected terrain) level, with a Universal Transverse Mercator (UTM) projection and a World Geodetic System WGS 84 datum. Four Landsat scenes wholly cover the study area with band 2–7 and 9 were chosen for lineament extraction. The characteristics of band used in the study are shown in table 1. There were 4 main steps applied for the lineaments extraction and analysis as shown in figure 2.

3.2. Methodology

3.2.1. Input data. The first stage of the methodology was selection of initial input data for lineament extraction. Although the lineaments can be extracted from numerous data sources such as aerial photographs, geophysical data etc. However, the Landsat 8 OLI images were preferred for the application in this study.
Table 1. The band characteristics of Landsat 8 OLI used in this study.

| Landsat 8 OLI Bands | Type of bands     | Wavelenght (μm) |
|---------------------|-------------------|-----------------|
| Band 2              | Blue              | 0.452-0.512     |
| Band 3              | Green             | 0.533-0.590     |
| Band 4              | Red               | 0.636-0.673     |
| Band 5              | Near-Infrared     | 0.851–0.879     |
| Band 6              | Shortwave-1       | 1.566-1.651     |
| Band 7              | Shortwave-2       | 2.107-2.294     |
| Band 9              | Cirrus            | 1.363-1.384     |

3.2.2. Improve quality of dataset. Principal Component Analysis (PCA) is a statistical method widely used in lineament studies. It has the advantage of compressing the information contained in initial bands into new bands called Principal Components (PCs) [6, 7]. Subsequently, this transformation removes the redundancy of data, isolates noise, and then improves the targeted information in the image [8]. Numerous studies have been based on the PCA in the detection of lineaments [6]. Then, a standard PCA transformation was performed for the spectral regions of VNIR and SWIR of OLI in this study.

3.2.3. Lineament extraction. Lineaments were automatically extracted from the PCA image. The Canny edge detection algorithm [9] was applied for extracting lineament frequency, length, orientation and other characteristics. Then PCA: band 3 was selected as mentioned in Han, Liu [10] that this band can be highlighted the geological differences. The step for lineaments extraction was used the Canny edge detection algorithm for transforming raster data to vector data format which matched for the line extraction.

3.2.4. Classification of the lineaments extraction. Existing geospatial data including geological lineament, stream network, and road network dataset were used for comparing and accuracy checking with the results and reported as statistics and direction of a total lineaments extraction.
4. Results and discussion

4.1. The result of quality improvement

The results of quality improvement were images of PCA analysis. Figure 3 shows PCA band 1 to 4 characteristics and statistics which were helpful in selection Band for lineaments extraction. The result showed that PCA: band 3 had difference of positive and negative values which can see the earth characteristics more clearly in the study area.

4.2. Comparison

Figure 4 is shows the result of lineaments extraction by comparison with topography of the study area. And comparison the relationship between the results of extract lineaments with four data was geological lineament data, stream data, and road data (figure 4).

| PCA: Band | Maximum (Unit) | Minimum (Unit) | Standard deviation |
|-----------|----------------|----------------|--------------------|
| 1         | 597.198        | -38.271        | 58.816             |
| 2         | 66.187         | -114.961       | 6.331              |
| 3         | 86.640         | -22.754        | 3.219              |
| 4         | 53.412         | -57.226        | 0.985              |

Figure 3. Characteristics of Landsat 8 OLI after applied PCA method.
Figure 4. (a) and (b) The results of lineaments extraction from PCA: band 3, compared with existing dataset including (c) geological lineament, (d) stream network and (e) road network.
Population (No. of line) 3,104
Population of Geological lineament (No. of line) 1,318
Population of Stream (No. of line) 637
Population of Road (No. of line) 224
Maximum Length of Geological Lineament (m) 4.00
Maximum Length of Stream (m) 3.00
Maximum Length of Road (m) 42.20
Mean Length of Geological Lineament (m) 2.00
Mean Length of Stream (m) 1.00
Mean Length of Road (m) 42.00
The Relationship with Geological Lineament (%) 42.46
The matched with Stream (%) 20.52
The matched with Road (%) 7.22
The main direction of lineament N-S

Figure 5. Orientation of lineament and statistics of the extracted lineament.

(a) (b)

Extracted Lineaments
Existing Geological Lineaments

Extracted Lineaments
Existing Road Network

Figure 6. Examples of error on the extracted lineaments when compared with (a) existing geological lineament and (b) Road network.

4.3. Statistics of lineaments extraction
The orientation allows identifying the most frequent directions of lineaments [6]. Therefore, they can be compared with directions relating to existing geospatial dataset in the study area. This step was done using the rose diagram. With an angular spacing of 45 degree and reported statistics such as maximum length, mean length (figure 5). The rose diagram discovered lineaments in various directions, but the main direction of this study was in North-South direction (figure 5) (N-E).

4.4. The errors of extracted lineament
There were some errors that might occurred from the analysis steps such as uncorrelated (figure 6a) and discontinued (figure 6b) of the extracted lineaments when compared with the existing geospatial dataset.

5. Conclusions
Based on Landsat 8 OLI remote sensing images together with principle component analysis and Canny edge detection techniques, we could extract lineament in Phayao Fault zone in north of Thailand.
To avoid noise affecting of the results, principle component analysis was applied as it removed the correlation between bands and highlight the differences in hue and texture saturation of the image. The Canny edge detection method not only highlighted the edges of linearity but also effectively reduced the noise. However, the comparison of the extracted lineaments with the existing geospatial dataset including geological lineament, stream network and road network could contribute to the understanding the relationship between the lineaments and the structural elements in the study area. However, there were some errors occurred such as gapped, discontinued, disconnected and uncorrelated lines. Therefore, the improvement of method might be concerned in the future study.

6. Acknowledgments
We would like to thank the Department of Mineral Resources, Thailand and U.S, Geological Survey (USGS) for providing the dataset used in the study. We would like also to acknowledge the 3rd LEAF committee for giving the opportunity to publish this research.

References
[1] Marghany M and Hashim M 2010 Int. J. Phys. Sci. 5 1501-7
[2] Hashim M, Ahmad S, Johari M A M and Pour A B 2013 Adv. Space Res. 51 874-90
[3] Hammad N, Dijdel M and Maabedi N 2016 Estudios Geologico 72 e049
[4] Elmahdy S I and Mohamed M M 2016 Geomat. Nat. Haz. Risk 7 600-19
[5] Klint K E S, Engstrom J, Parmenter A, Ruskeeniemi T, Liljedahl L C and Lehtinen A 2013 Geol. Surv. Den. Greenl. 28 57-60
[6] Adiri Z, Harti A E, Jellouli A, Lhissou R, Maacha L, Azmi M, Zouhair M and Bachaoui E M 2017 Adv. Space Res. 60 2355-67
[7] Gabr S, Ghulam A and Kusky T 2010 Ore Geol. Rev. 38 59-69
[8] Amer R, Kusky T and Mezayen A E 2012 Adv. Space Res. 49 121-34
[9] Canny J 1986 IEE Trans. Pattern Anal. Mach. Intell. 8 679-98
[10] Han L, Liu Z, Ning Y and Zhao Z 2018 Adv. Space Res. 62 2480-93