Feature Extraction in Parallel with Georeferencing for the Digitalization of Historical Maps

Tyng-Ruey Chuang
Institute of Information Science
Academia Sinica
128 Academia Road, Section 2
Nangang, 115 Taipei City, Taiwan
trc@iis.sinica.edu.tw

Chiao-Ling Kuo
Center for GIS, Research Center for Humanities and Social Sciences, Academia Sinica
128 Academia Road, Section 2
Nangang, 115 Taipei City, Taiwan
kuo@chiaoling.com

Jheng-Hong Lai
Center for GIS, Research Center for Humanities and Social Sciences, Academia Sinica
128 Academia Road, Section 2
Nangang, 115 Taipei City, Taiwan
laigis@gate.sinica.edu.tw

Hsiung-Ming Liao
Center for GIS, Research Center for Humanities and Social Sciences, Academia Sinica
128 Academia Road, Section 2
Nangang, 115 Taipei City, Taiwan
veevee@gate.sinica.edu.tw

Huang-Sin Syu
Institute of Information Science
Academia Sinica
128 Academia Road, Section 2
Nangang, 115 Taipei City, Taiwan
gipong@iis.sinica.edu.tw

Abstract

This paper is a study on the digitalizing process for historical maps, with an emphasis on the design of a workflow for enabling a participatory approach to large-scale knowledge extraction from map images. We propose to separate the task of image feature extraction from the task of georeferencing when digitizing historical maps. The two tasks are independent to each other and can be performed in parallel. Image features already extracted shall be reused, and their spatial properties re-calculated after the map image is re-rectified. We describe in detail such a parallel workflow in this paper. We validate the feasibility of the proposed workflow by applying it to the digitalization of the 1896 Rapid Charting Map of Tainan Prefecture.

Keywords: image feature extraction, georeferencing, historical map, workflow, Tainan, Taiwan

1 Motivations

Historical maps are rich sources of diverse information about the places we live in today, revealing how the present is related to the past. In this paper, we focus on historical street maps and neighborhood maps, and look into the processes in correlating map features with current places. The traditional process can be very labor intensive: Paper maps are digitized into images, the images are georeferenced, features are identified and their contours traced, and then the features are extracted into digital objects annotated with proper attributes.

When an old map is georeferenced, it becomes much more useful as features in the map can be compared with those on a modern reference map; it also make possible to visualize the change over time for regions on the map. However, old maps often have unknown projection, and as such without appropriate geometric correction, the accuracy of the georeferenced map image can be difficult to judge. Different rectification schemes, and the choices of control points, all introduce various inaccuracy in converting map images to standard map coordinate systems.

This task dependency is a barrier when considering a large-scale, participatory approach to knowledge extraction from historical maps. In the participatory approach, a large number of volunteers are involved in the extraction of information from a large collection of historical maps. The volunteers participate in identifying and transcribing map features into a structural data format for better reuse. In the past they can proceed to do their work only after the scanned map images have been georeferenced. As the task of georeferencing often is in the hand of a few domain experts, this creates a bottle neck.

2 The Traditional Workflow

Traditionally two major tasks are involved in the digitization process of historical maps: georeferencing and feature extraction. Usually the two tasks are performed in sequence. For georeferencing, the scanned image of the historical map is overlayed onto a reference map with a well-defined geographic coordinate system. The scanned image is georeferenced by pairing up control points in the scanned image with their corresponding points in the reference map. By way of interpolation and some calculation, projection coordinates are derived for pixels in the scanned image. After georeferencing, features in the scanned images — placename labels, administrative boundaries, road networks, etc. — are identified and vectorized into digital objects. In their digital forms, these features have all kinds of attributes including their projection coordinates. This task is called feature extraction.

The choice of control points, however, can be subjective. So is the selection of the reference map itself. As a result, a map image can be georeferenced differently. The mapping from image pixels to geospatial coordinates depends on many factors (control points, interpolation methods, reference maps, etc.). Features in a map image may need to be extracted again after the image is georeferenced anew. This process can be repetitive and tedious.

3 A Parallel Workflow

We propose and experiment with a parallel workflow, shown in Figure 1, in which feature extraction is performed independently of georeferencing when digitizing historical maps. In the left, Figure 1 shows the traditional workflow where feature extraction follows georeferencing. In the right is the proposed parallel workflow where feature extraction is performed on the source map without it being first georeferenced. Spatial attributes of the extracted features, such as the boundary of a building block, are expressed in image pixel coordinates.

Once the source map is georeferenced, the transformation that maps image coordinates to projection coordinates is used to transform spatial attributes (relative to the image coordinate) of the extracted features to their geographic attributes (relative to the projection coordinate). In Figure 1, the affine transformation is used as an exemplar transformation for georeferencing, and the GDAL (Geospatial Data Abstraction Library) is used both as the library for the georeferencing task, and for computing the parameters for the affine transformation. This workflow, however, can be applied to other transformations and libraries.

4 The Affine Transformation

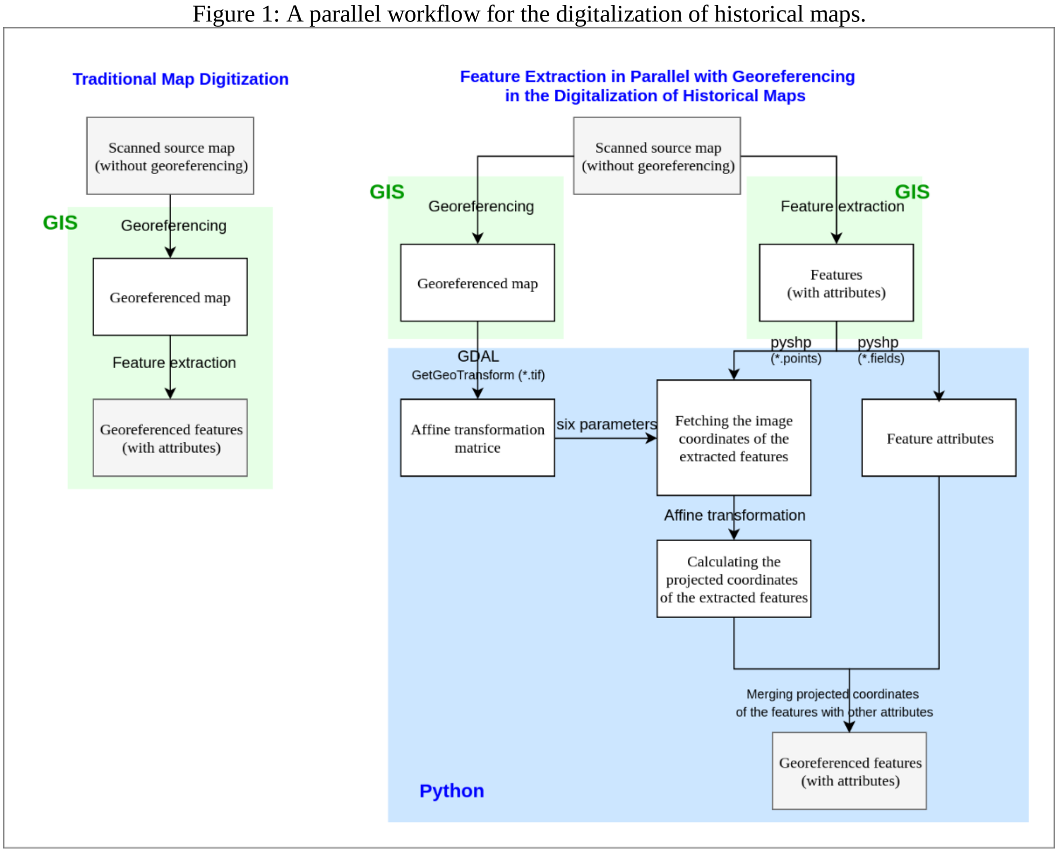
The affine transformation can be expressed as a combination of translation, scaling, rotation and shearing so it can be collapsed into a single homogeneous matrix which can be written as in the following equation:

$$\begin{bmatrix} E \\ N \\ 1 \end{bmatrix} = \begin{bmatrix} S_x \times \cos\theta & S_y \times (-\sin\theta) & t_x \times S_x \times \cos\theta + t_y \times S_y \times (-\sin\theta) \\ S_x \times \sin\theta & S_y \times \cos\theta & t_x \times S_x \times \cos\theta + t_y \times S_y \cos\theta \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} \quad (1)$$

where

E is the calculated projection easting of the pixel on the map,
N is the calculated projection northing of the pixel on the map,
x is the column number of the pixel in the scanned image counting from left,
y is the row number of the pixel in the scanned image counting from top,
S_x scales in x-direction,
S_y scales in y-direction,
t_x translates in x-direction,
t_y translates in y-direction,
$S_x \times \cos\theta$ is the dimension of a pixel in map unit in x-direction,
$S_y \times \cos\theta$ is the dimension of a pixel in map unit in y-direction,
$S_x \times \sin\theta$ is a rotation term,
$S_y \times (-\sin\theta)$ is a rotation term,
$t_x \times S_x \times \cos\theta + t_y \times S_y \times (-\sin\theta)$ is a translation term,
$t_x \times S_x \times \sin\theta + t_y \times S_y \times \cos\theta$ is a translation term.

Figure 1: A parallel workflow for the digitalization of historical maps.



5 Neighborhoods in the Tainan Prefecture: Then and Now

In this section we illustrate the parallel workflow by showing the steps we did in digitalizing the 1896 Rapid Charting Map of Tainan Prefecture. This map was produced in 1896, one year after the Japanese first ruled Taiwan. Tainan has been considered as one of the oldest cities in Taiwan. The city was established in 1624 by the Dutch as a trading post but later populated by people from the the mainland China. The 1896 map is a 1:5000 city map with detailed information about the streets, neighborhoods, and landmarks (mostly temples) in Tainan covering roughly the area inside the old city wall. It is a proportional map made with modern charting methods. The map looks rather precise but includes no information about the coordinate system it used.

Figure 2 is a scanned image of 1896 Tainan map. Figure 3 shows all the extracted street and building blocks from the map. In total, 885 polygons have been extracted. In addition, we transcribed 235 labels from street/neighborhood/landmark names in the map. The polygons and labels are numbered, each with its own identifier, and all cross-referenced. Figure 4 shows a part of the map image in which the name label {天公壇} (Tian Gong Temple) was underlined and numbered (124) in blue. The two blocks to which the label refers were traced in red and also numbered (15 and 123). Table 1 is a part of the cross-reference table in which label #124 is shown to be associated to blocks #15 and #123. Table 2 shows the location of block #123 in the scanned map. Vertices of the polygon are positioned by their image coordinates.

Figure 2: The 1896 Rapid Charting Map of Tainan.

Figure 3: Street blocks from the 1896 map image.

Figure 4: Blocks #123 & #15 in the 1896 map image.

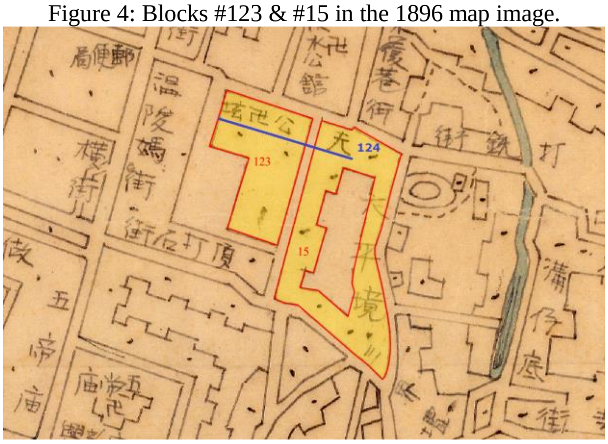


Table 1: Street names and building blocks.

Label Id	Street Name	Block Id
124	天公壇 (Tian Gong Temple)	15,123
125	太平境 (Tai Ping Neighborhood)	15
126	溫陵媽街 (Wen Ling Ma Street)	65,145,603,604
127	三界壇 (San Jie Temple)	15,185

Table 2: Image coordinates of block #123.

The location of block # 123 (a polygon)
(2694.403934896596, -4566.473498063593)
(2839.4213609321, -4615.012388596138)
(2779.496804719082, -4828.943054276613)
(2695.0031804587265, -4799.580021732234)
(2731.5571597486673, -4681.528645992588)
(2664.441656790087, -4661.753542442292)
(2694.403934896596, -4566.473498063593)

Figure 5: Control points in the 1896 map image.

Figure 6: Control points in the 2018 Google Map.

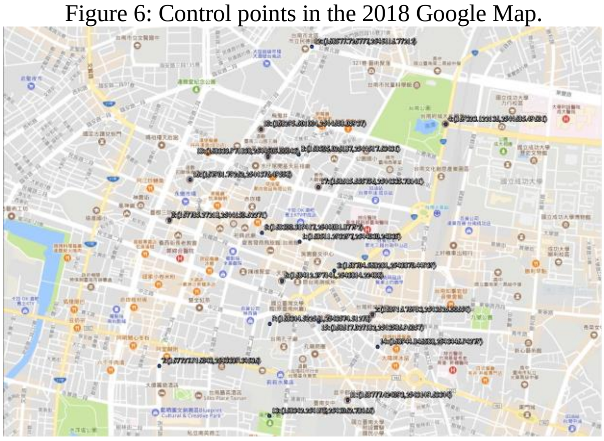
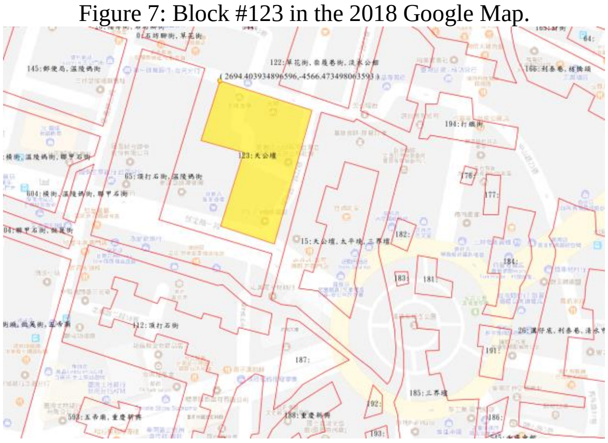


Figure 7: Block #123 in the 2018 Google Map.



We have selected 19 control points in the 1896 map for georeferencing purpose. These control points are selected either because their remains are easy to locate in the current city (and the current map) or because they are old temples whose locations have not been moved. The locations of the 19 control points, along with their image coordinates, in the 1896 map are shown in Figure 5. Figure 6 shows the locations of the 19 control points in the 2018 Google Map. The 1896 map image is georeferenced — with the 2018 Google map as reference map — by the use of the 19 control points. GDAL is used for this task, and the parameters for the corresponding affine transformation are also computed by a call to the GDAL library.

After the georeferencing, the location of block #123 in the 2018 Google Map can be computed by applying the affine transformation to the image coordinates of the block in the 1896 map image (cf. Table 2). This results in Table 3 in which the projection coordinates of block #123 are shown. Figure 7 is an overlay upon the 2018 Google Map of the blocks and labels extracted from the 1896 map image. Block #123 is highlighted in Figure 7. The location of block #123 is positioned very close to the current day Tian Gong Temple which is where it shall be. Figure 8 is the result of overlaying all the street blocks extracted from the 1896 Rapid Charting Map upon the 2018 Google Map.

Table 3: Projection coordinates of block # 123.

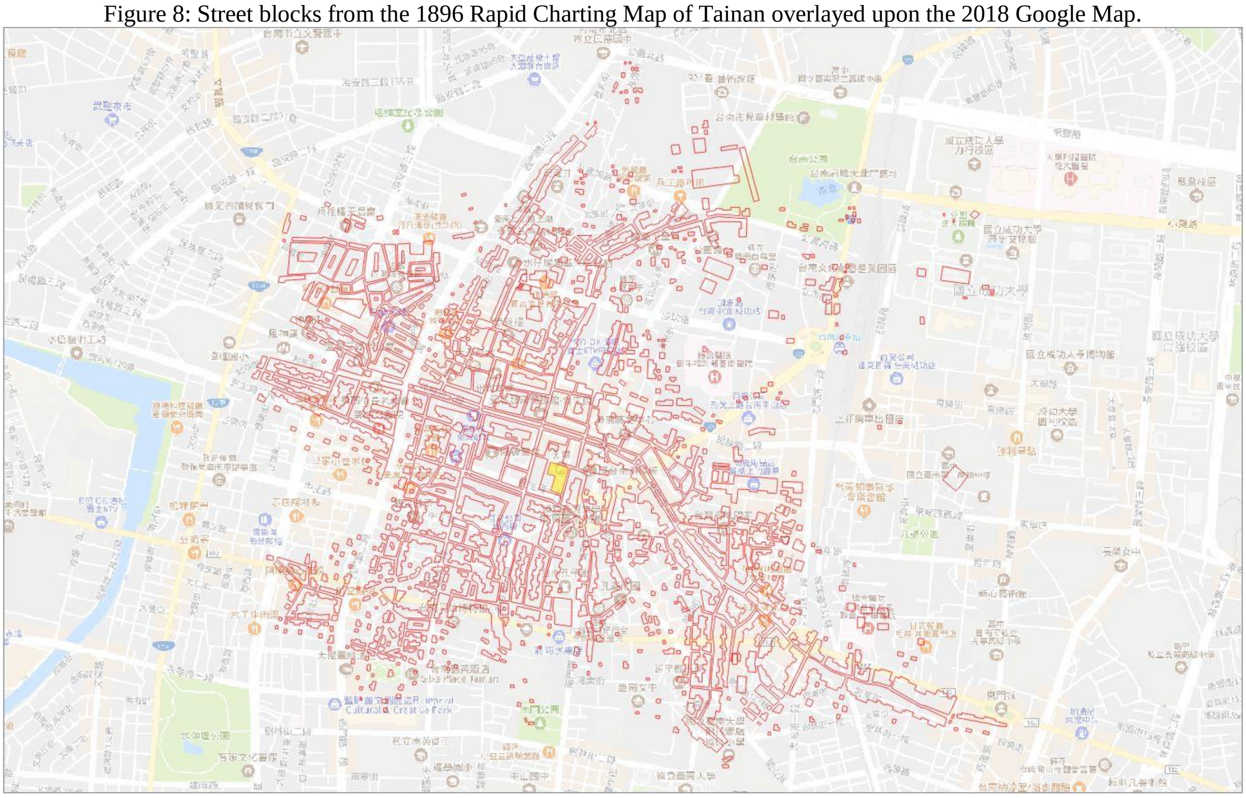
The location of block # 123 (a polygon)
(168379.99486602467, 2543833.2661003214)
(168435.80670141568, 2543815.3724147896)
(168412.97499895855, 2543734.1945785866)
(168380.45546441118, 2543745.0298509016)
(168394.39509239697, 2543789.836999154)
(168368.56747676068, 2543797.100435504)
(168379.99486602467, 2543833.2661003214)

6 A Work in Progress

The work reported in this paper is still in progress and is in need of much refinement. Although we are confident of the usability of the proposed workflow, we have not actually put it into use in a participatory sitting where volunteers are invited to work on image feature extractions. Currently we use QGIS to validate this work, but we will need to find and experiment with crowdsource platforms of online image feature extraction. A further integration of crowdsourced georeferencing with crowdsourced image feature extraction is also possible.

There is a wealth of literature on exploring and processing old maps (EOM, 2016; EOM, 2017). How better to automate part of the process without sacrificing the quality of the extracted information, nevertheless, remains elusive. As an example, in georeferencing, the problem of selecting a good model to correct geometry distortion still persists. Most studies still focused on applying various technique to rectify the scanned image such as using constrained polynomial fit (Moln´ar, 2010), a polynomial-based approach (Brovelli and Minghini, 2012), or using various types of features or various image registration techniques (Long, Jiao, He et al., 2015; Shaker, 2004; Shaker, Easa, S. et al., 2017; Yan, Easa and Shaker, 2017). These factors will be taken into consideration when we refine our current implementation.

Figure 8: Street blocks from the 1896 Rapid Charting Map of Tainan overlayed upon the 2018 Google Map.



References

Brovelli, M. A. and Minghini, M. (2012) Georeferencing old maps: a polynomial-based approach for como historical cadastres, *e-Perimetron* 7(3), 97–110.

EOM, *International Workshop on Exploring Old Maps (EOM 2016)* University of Luxembourg, 2016.

EOM, *Second International Workshop on Exploring Old Maps (EOM 2017)* Universit¨at Wu¨rzburg, 2017.

Long, T., Jiao, W., He, G., Zhang, Z., Cheng, B. and Wang, W. (2015) A generic framework for image rectification using multiple types of feature, *ISPRS Journal of Photogrammetry and Remote Sensing* 102, 161–171.

Moln´ar, G. (2010) Making a georeferenced mosaic of historical map series using constrained polynomial fit, *Acta Geodaetica et Geophysica Hungarica* 45(1), 24–30.

Shaker, A. (2004) The line based transformation model (lbtm): A new approach to the rectification of high-resolution satellite im- agery, *The International Archives of Photogrammetry, Remote Sensing, and Spatial Information Sciences*, Istanbul, Turkey, XXXV (3),(on CD-ROM).

Shaker, A., Easa, S. M. and Yan, W. Y. (2017) Improved param- eter estimation of the line-based transformation model for remote sensing image registration, *Journal of Imaging* 3(3), 32.

Yan, W. Y., Easa, S. M. and Shaker, A. (2017) Polygon-based image registration: a new approach for geo-referencing historical maps, *Remote Sensing Letters* 8(7), 703–712.