On the Use of Historical Archive of Aerial Photographs for the Discovery and Interpretation of Ancient Hidden Linear Cultural Relics in the Alluvial Plain of Eastern Henan, China

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Purpose of this work

• **This paper:** We are interested in the additional interpretative rules, including scale, continuity, shape and clustering, for identifying hidden linear ancient cultural relics using historical archive of aerial photographs on the alluvial plain of eastern Henan, China. We also highlight the significance of historical archives for archaeology in regions where evident changes occurred in past and obscured traces of ancient human activities.

• **Motivation:** China has a long history of more than 5,000 years, and Henan province, in the central China, has continual cultures more than 8,000 years. The frequent flooding of Yellow river formed the alluvial plain of eastern Henan, and in this area, a large amount of relics and sites are buried by natural reasons, or destroyed by human activities. How to investigate and find signs of relics or sites in this area, it is a difficult thing for archaeology. For this reason, traditional investigation methods no longer satisfy the requirements of archaeological inspection in this region; and remote sensing techniques were therefore introduced to aid in archaeological studies.

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Eastern Henan, China, includes 2 cities of Shangqiu and Zhoukou (including 19 counties). The Yellow River alluvial plain is the dominant geomorphic feature. The Yellow River caused inundation and silting many times in this area, which wrought great havoc on the natural and cultural landscape of the region.

The ancient cultural relics in Eastern Henan are dense and rich, with cultural continuity and a long-enduring history. As a result, the region is abundant with ancient architectures and artificial canal relics. However, the repeated inundation of the Yellow River buried many historical relics underground.
The surface landscape in the alluvial plain of Eastern Henan has undergone enormous changes in recent decades because of the rapid development of the regional economy and the urbanization process. Therefore, the images were selected: the years of 1958 and 1972. The former, basically covered the entire study area (totally 500 images), was used as the primary data with a spatial resolution of 1 m. The latter was used as the supplementary owing to its limited amount and spatial coverage, with a scaling of 1:50,000 and a spatial resolution of 2.5 m.
All the images collected for the area were visually interpreted and the images with obvious features of ancient cultural relics were screened. We further analyzed the selected regions of interest image slices according to historical documents and archaeological clues, which helped us to avoid overlooking key relics. The images of the key area and the images with indistinct features of ancient cultural relics were enhanced. Local spatial analyses based on Geary, Getis and Moran Index should emphasize the presence of edge, cluster at diverse scales of investigation. Results from spatial correlation facilitate the interpretation or may be further elaborated (generally using classifications) before interpretation.

GIS based Image: Geocoding, Mosaicking, Mapping, and Positioning

According to a topographic map with a scaling of 1:50,000, screened images were further geo-coded in ArcGIS. Because of the frequently occurrences of the relics, the large number of images concerning the same region was mosaicked to derive a larger macroscopic environmental landscape.
the detected sites of hidden linear cultural relics:

1. large-scale man-made ditch/canal

2. Dock relics in Shangqiu

3. Circular moat relics in Luyi
1. Large-scale Man-made Ditch Relics

To enhance both the modern landscape features and the traces of past human activities, we used visualizations based on the RGB obtained from Getis-Ord, Geary's, Moran's maps. From the upper part it is possible to clearly identify traces of an ancient canal around the Kaihuangdian area as well as the relics (inside the red box) centered around Shangqiu City indicating a circular, Z-shaped continuous distribution. The sharpened features inside the red box show that the use of spatial analysis enables us to highlight subtle traces, especially those that are less clearly evident from the black/white photo.
The aerial images showed obscure, bent line-shaped, dark-colored, strip-form objects. The line segments ranged from dozens of meters to nearly 100 m in length, with widths of only a few meters. The bend angles were mostly obtuse. Those objects showed good continuity, with almost no breaks. Majority of them were hidden objects beneath the surface. The color tone of the convex segment was darker than elsewhere. This segment was preliminarily determined as the explicit object aboveground. The bent line-shaped feature encircled part of the village and then meandered away. According to our visual interpretation of the aerial images, the dark grey or black serration should be positive soil mark. The color tones and shadows of the relics were not distinguishable from surrounding objects. However, the unique geometry and continuous distribution of the relics could be used as the archaeological mark for the imagery interpretation.
The interpretation map shows that the relics have a large distribution scope, covering nearly all of Shangqiu City, presenting the shapes of incomplete inner and outer rings. The length of the outer ring is 140 km, including the bifurcation in the northeast. The inner ring is located in the southeast of the old district of Shangqiu. The length of the inner ring is approximately 30 km. The total length of the relics is approximately 170 km, covering an area of about 1000 km².
According to the shapes, color tones, and textures of the relics on the images and field investigations of the explicit relics aboveground, we speculate that the serrated linear objects are artificial ditch relics in ancient times. However, we did not find any detailed or clear historical records for this large-scale infrastructure. We found remains in Han Dynasty (2000 aBP) surrounding the relic site through past field investigations. Shangqiu was the capital of the state of Liang, the vassal state of the Han Dynasty. According to the historical record, Liu Wu (Prince Xiao of Liang) ordered a massive construction in Liang centered on Suiyang city (Shangqiu). Taking advantage of the natural scenery, a large garden was built and called Dongyuan. Later generations called this garden "Liangyuan Garden". The large-scale man-made ditches on remote sensing images resembled Liangyuan Garden in terms of location and scale. Therefore, we speculate that the relics are closely associated with Liangyuan Garden, which is further confirmed by the antiques in Han Dynasty discovered.
Two sites of suspected canal and dock relics were discovered. They are located at Zizhuang Village, in Ningling County and Qingliangsi Village, in Shangqiu County, respectively.

Relics in Zizhuang Village:
- It is shown as a regular triangle on the image, with obvious features of artificial construction.

Relics in Qingliangsi Village:
- As a near-trapezoid shape on the image,
It shows two diverse false colour compositions based on spatial indices. In particular, Up depicts RGB composite made of Getis and Moran indices that clearly emphasizes the hidden relics in Zizhuang. Down shows a false colour composite based on Getis and Geary products which clearly shows the current land use. One of the most important added values obtained from the use of spatial correlation is that according to the diverse visualizations it is possible to enhance the current land use and land cover types or to better emphasize the traces of past human activities still fossilized in the modern landscape. All of these information can be particular relevant not only for improving the knowledge of the investigated areas but also for supporting sustainable management strategies to preserve archaeological remains. This comparison clearly puts in evidence the significance of historical archives providing a strategic “second life” especially for archaeological investigations conducted in areas, as those we herein analyzed, that in the last years have been involved in evident changes in land use and land cover that tend to obscure traces of past human activities.
3 Circular Moat Relics in Luyi

The relics shown on images indicate continuous circular lines composed by several segments. With Jiatan as the center, the relics have a circular distribution in the periphery. The features of artificial construction are particularly obvious in the west and south, but are not obvious in the north. The southeast part of the relics has been destroyed by the construction of modern roads and therefore lacking of obvious interpretive features.
The discovery of several sites with similar relics indicates that the circular patterns surrounding the settlements are widespread. Moreover, the settlements have similar circular patterns at various county, township and village levels. This further confirms the widespread presence of such relics in the periphery of settlements in this area.
Results from our investigations clearly pointed out that although the aerial photo-based features of the hidden relics below the surface can be summarized as shadow, vegetation, and soil marks, they are subject to many disturbances due to regionality, pertinence and complexity of surface landscape. These interpretative marks may be of low operability in the interpretation of hidden relics and they may be improved using additional parameters such as scale, continuity, shape and clustering.
The investigations we carried out clearly pointed out that the interpretation based on both traditional archaeological marks and the above discussed additional parameters (scale, continuity, shape and clustering) can facilitate the discovering of hidden linear relics. This approach was fruitfully adopted for the historical aerial photographs acquired for the alluvial plain of eastern Henan (China) and can be applied to similar environmental and cultural settings for the detection of features such as roads, roman centuriations, Neolithic settlements, etc characterized by geometric clusterized features with linear or circular shape, respectively.
Conclusions

• Using totally more than 700 historical archive of aerial photos, we discovered a large number of hidden linear cultural relics in the alluvial plain of Eastern Henan province, China. The discovered relics are large-scale artificial ditch, canal and dock relics in Shangqiu and circular moat relics in Luyi. They were further validated by historical documents in conjunction with a recent progress in the field archaeology for a rough estimation of the cultural properties and types of the newly discovered ancient cultural relics.
Based on our study conducted in Eastern Henan, we propose additional interpretative rules for hidden linear cultural relics on the alluvial plain excepted for the conventional marks of shadow, vegetation, and soil; they are combined features of scale, shape, continuity and clustering. In conjunction with traditional archaeological marks, the proposed parameters make more operable and pertinent for the use of aerial photographs in the detection of hidden linear ancient cultural relics on the alluvial plain.
• Playing as a strategic “second life” for archaeological investigations, our study puts in evidence the great importance of historical archives as those we herein analyzed, particularly for regions where evident changes occurred in recent years and tend to completely obscure traces of past human activities. Our future study will focus on the integration of the results from high multispectral images, geophysical surveys and field archaeological explorations.
Other Cases

- Document of ancient city
- Monitoring of cultural heritages

Cultural heritages, a need of monitoring and policy-making for protection. Since 1950s, China has an enormous change of the land use and cover. When we try to know more information about some cultural heritages, the historical archives of aerial photographs become scarce and important. The historical aerial photographs and satellite data, that can be used to derive information to transform data into information or knowledge for archaeology and cultural heritages protection.
Case 1: Historical archives of aerial photographs can be used to check the landscape of ancient city.
Google earth image
Yin Xu site, the first relic of the capital of the Shang Dynasty literally recorded and confirmed by oracle bone scripts and archaeological excavation in China, dates back more than 3,300 years, located in Anyang City of Henan Province. It is inscribed on the UNESCO list of World Heritage Sites in 2006.
It covers an area of around 36 km², and consists of four parts: (a) the Middle Shang City site in the North of the Huanhe River, (b) the Site of the Royal Tombs, (c) the Site of the Palace and Royal Ancestral Shrines and (d) the Site of Hougang.
The rapid development of urbanization in China has brought the pressure of the cultural heritage protection, especially the cultural heritage located in the town or nearby towns. It has been found or reported the illegal construction events occur frequently within the heritage area, such as Sina News February 25, 2014 reported, in the north of the construction control area of Sites of the Palace and Royal Ancestral Shrines next to the Huan River, a row of eight sets of three-layer piece "villa" has been built to the sixth row.
How the Residential Areas in the protected areas expanded?

- The historical aerial photographs and satellite images were used to identify the changes of Residential Areas in Yin Xu site in year 1968, 1998, 2005 and 2013.
- In this study, terrain data, planning maps, field survey data also were collected.
During 1968-2013, the residential area is more than doubled, increasing residential area in the site is the main factor causing tremendous pressure on the Yin Xu heritage conservation.
During 1968-2013, the important relics sites continue to be found in the region, it continued to increase the site area, indicating the need to dynamic monitor for the changes of land cover.
The expanding of Xiaosikong village in the centre of Yinxu site
Thanks!

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