Different Numerical and Visual Concepts for Combining Aerial Pictures and Geophysical Mappings

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Abstract

Aerial archaeology and geophysical surveys – two of the most powerful tools for archaeological prospecting – complete each other very efficient. Aerial photography is essential for detection and for a first classification of archaeological sites. Geophysical mappings, which are much more time-consumable than aerial prospecting, enable not only detailed but also three-dimensional studies of the remaining of settlements, independent of the period of time the settlement was occupied. The results of these both archaeological prospecting tools provide a lot of information to the archaeologist for the documentation of sites which should not be excavated and therefore should remain uncovered in the earth, well preserved for future generations, or the archaeologist can use their results to prepare an excavation most effectively.

Résumé

Les deux outils de prospection archéologique les plus puissants - la photographie aérienne et les prospections géologiques - se complètent très efficacement. La photographie aérienne joue un rôle essentiel dans la détection et la première classification des sites archéologiques. De son côté, la prospection géophysique, qui prend beaucoup plus de temps, nous permet d'obtenir des études détaillées, même en trois dimensions, des restes d'habitation, quelle que soit la période. Les deux méthodes fournissent donc à l'archéologue un ensemble d'informations pour documenter les sites qu'il faudrait soit fouiller, soit conserver in situ et préserver pour les générations futures. L'archéologue peut aussi utiliser cette information pour préparer plus efficacement la fouille.

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1 | Intention for the numeric combination

Normally, the combination of aerial picture and geophysical data is based on rectified aerial pictures (fig. 1). This combination is not only an important tool for the archaeologists' work as stated in the last paragraph, but also an impressive documentation

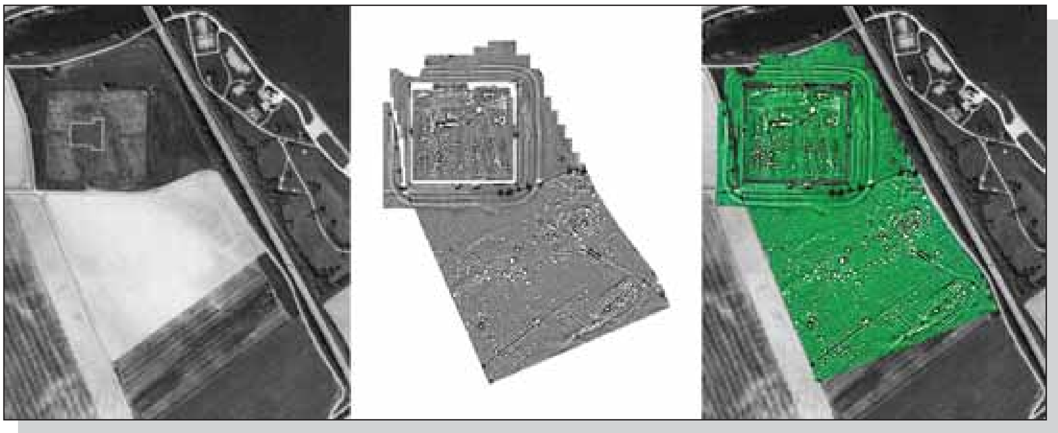

Figure 1: Conservative combination of a rectified aerial picture and geophysical data: The roman fort and part of a vicus located in Rainau-Buch, Ostalbkreis, Baden-Württemberg, Germany. Aerial picture by Otto Braasch

of archaeological sites, which is most suitable for the presentation in a museum and in publications and for presenting the results of archaeological prospecting to non-specialists. But if the results of geophysical investigations show not too many anomalies, which are based on archaeological structures, the combination of aerial picture and geophysical mapping need not be based on rectified aerial pictures. If there are sufficient corresponding structures in the aerial picture and in the geophysical mapping, the image containing the results of the geophysical survey can be stretched and inclined corresponding to the inclination and orientation of the aerial picture (fig. 2). We use this kind of visualisation if aerial pictures can not be rectified because of lack of sufficient points of reference, and in addition if the area of geophysical mapping is not sufficient large to calculate a rectification based on the geophysical mapping.

Figure 2: The combination of aerial picture and geophysical mapping need not be based on rectified aerial pictures. The image containing the results of the geophysical survey can be stretched and inclined corresponding to the inclination and orientation of the aerial picture. Celtic structures at Mengen, near Sigmaringen, Baden-Württemberg. Aerial photo by Otto Braasch

2 | Numeric combination using alpha-channels

Figure 3: Numeric combination using alpha channels: Archaeological structures of a roman villa rustica (Ohrnberg, Baden-Württemberg) already seen in the aerial picture are enhanced. Structures which can be seen very weakly in the aerial picture, but quite good in the geophysical mapping are emphasised. Aerial photo by Otto Braasch

The combination of aerial picture and the results of geophysical mapping described above points out one disadvantage: the result of the geophysical mapping conceals corresponding areas of the aerial picture. So we were looking for some new concepts which enable to make the aerial picture more transparently in the area covered by the results of the geophysical surveys. At this time we suggest two new concepts for a numerical combination to overcome the problem just mentioned. The first concept uses alpha channels (which is equivalent to a 4th level in RGB-pictures and a 5th level in CYMK-pictures respectively). This level controls each pixel and decides if a specific pixel should be taken into consideration for the mathematical operation or not, which makes it possible to hide non-archaeological-based data in the results of geophysical mappings. This concept is demonstrated in figure 3: at the top of this figure the aerial picture, provided by Otto Braasch, of a Roman villa rustica (near Ohrnberg, Baden-Württemberg) is presented. To unite this aerial picture and the result of a geophysical survey (geoelectric mappings) it was necessary to do a suitable stretching and inclining of the image containing the geophysical data because of the lack of sufficient points of reference found in the aerial picture, to be able to rectify the aerial picture. At the bottom of this figure the result of the numeric combination, using alpha channels, is presented. This example demonstrates that the archaeological structures of a Roman villa rustica already seen in the aerial picture are enhanced using this kind of combination. Moreover structures which can be seen very weakly in the aerial picture, but quite good in the geophysical mapping are emphasised.

3 Numeric combination using algorithm

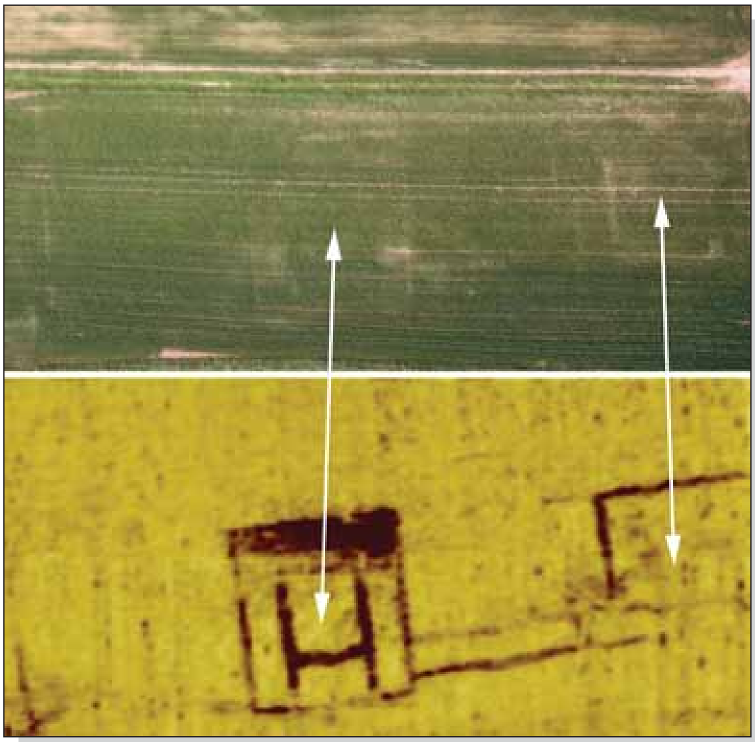

Figure 4: Aerial picture (provided by Otto Braasch) and one result of a ground-penetrating radar survey of a part of the roman town near Neuenstadt, Baden-Württemberg, Germany. Please note that structures, verified by the geophysical survey couldn't be seen in the aerial picture and vice versa (for example a wall of the eastern part of this roman sanctuary). North is to the top

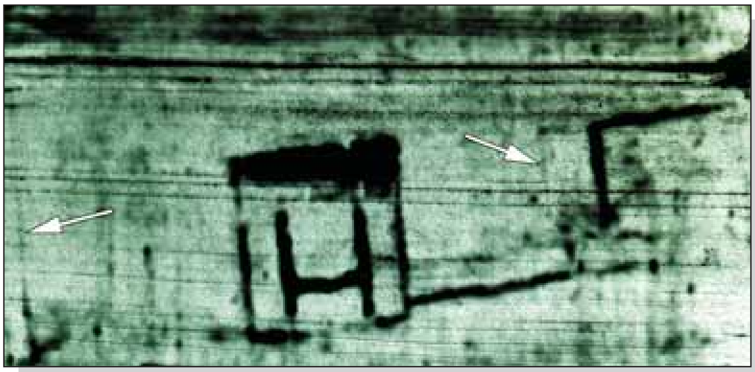

Figure 5: Result of the numeric combination of aerial picture and the result of geophysical mapping. Structures which are detected by both methods are enhanced. Structures, which are detected only by aerial archaeology (marked by two arrows) are not hidden by geophysical data

In opposite to the concept just discussed, the second method presented enables to do the controlling of the strength of the numeric combination. This strength is controlled by a parameter, which we found should be set lower than the value one. The numeric combination is based on the algorithm:

$$Cij = Bij + f/N^2(A^2ij \,.\, Bij - B^2ij \,.\, Aij)$$

with Cij: pixel at position (i,j) of the resulting image; Aij, Bij: pixel at the position (i,j) of the aerial picture and the picture with the result of geophysical mapping respectively; f: parameter, controlling the strength of the combination ($0 < f <= 1$); N: depth of the images (if greyscale, 8 bit, N = 256)

Figure 4 compares the aerial picture provided by Otto Braasch and one of the results of ground-penetration radar of a small part of the Roman town at Neuenstadt, Baden-Württemberg. Two arrows indicate the corresponding structures detected by aerial archaeology and confirmed by the geophysical survey of a roman sanctuary. Most of the walls of the roman buildings can be seen more clearly in the geophysical records. But there are also structures, based on subsurface walls, shown in the aerial picture but not in the results of the geophysical mapping. Because of this, this example, i.e. the aerial picture and the corresponding time slice (a time slice is the result of a ground-penetrating radar survey, indicating anomalies in a certain depth) of the radar survey are predestined to be combined using the algorithm presented here. The result of this numeric combination is presented in figure 5. We have inverted the aerial picture so that the walls are shown as dark lineaments and are therefore comparable to the dark lineaments of the time slices of the radar survey, which are corresponding to the subsurface structures based on roman walls. This figure contains the positive results of the both prospecting tools: the aerial archaeology and the geophysical survey. The lineaments (i.e. subsurface walls), which can be seen in the aerial picture but not in the geophysical mapping are indicated by two arrows in figure 5. The lineament in the western part of the aerial photo (north is to the top) is part of the wall, which surrounds the sanctuary. The other lineament is part of the eastern building of the roman sanctuary. At this time we have no idea why the ground-penetrating radar survey wasn't able to verify these lineaments.

4 | Conclusion

With figure 5 we demonstrated that an advantage of the numerical combination of photos provided by aerial archaeology and the results of geophysical surveys based on the algorithm presented here, is that structures, detected by aerial archaeology are not totally covered by the results of geophysical prospecting. Some kind of transparency enables to do a numeric combination of anomalies and structures, detected by the aerial archaeology as well as by geophysical mappings. This enhances structures which are detected by both methods, and prevents that structures, which are detected only by aerial archaeology are totally hidden by geophysical data, as it would be the case by using the usual employed conservative method, combining rectified aerial pictures and the results of geophysical mappings as demonstrated in figure 1.