USAGE OF STEREO ORTHOIMAGE IN GIS: OLD CONCEPT, MODERN SOLUTION

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ABSTRACT:

The main goal of this paper is to find answer for two questions: why stereo orthoimage (orthophoto) was forgotten, and furthermore, what conditions have to be fulfilled for this particular technique to be reanimated?
Stereo orthophoto concept was first introduced by Collins, during late seventies of last century (Colins, 1968). It has ignited huge interest, and many researchers were looking forward for its development (Blachut 1976, Kraus et al. 1976). However, after around twenty years, interest in stereo-orthophoto has shrunk, and during eighties of XX century it was almost extinct. Despite of fact that digital photogrammetry provides better conditions for it now than ever, it has never got chance for reactivation. There was but few papers about stereo orthoimage, and they are proposing continuous stereo ortho-mosaic generation while preserving its metric value (Li et al 2002, Wang 2004).
Reasons of downfall of this interest were examined, and it has been concluded that the main cause was usage of this technique in conjunction with analog photogrammetry. The radiometric value of orthophotomaps and stereo components developed on photosensitive paper were very low during that time. Equipment for observation and measurement were simply very big and therefore impractical. Authors have concluded, that nowadays sum of gains outweighs its flaws and it is reason enough to go back to it. But in a time of digital vector 3D models there is a need for proper strategy for popularization stereo orthophoto. Main point of this strategy would be encapsulating stereo orthoimage method into GIS tools, optimally open source. GIS have large numbers of consumers whom regard for orthophotomap (or orthoimage) is very high. If they were to be proposed with possibility of using stereo orthoimage inside a GIS tool, as a complementary to the orthophotomap, probably they would recon how much stereoscopy helps with interpretation of an image.
Authors have planned to develop software for utilization of stereo orthoimage available from the Quantum GIS interface, and test version is to be based on anaglyph stereoscopy. Value of creating continuous stereo-mosaic composed from many 3D models was assessed. Consensus was, however, that this solution surprises us with frequent perspective changes which leads to discomfort. As an outcome it was decided to focus on single stereo orthoimage pairs. When area constrains are specified for single model, one can load them as requested by an user. In case of increased lateral and longitudinal coverage, which is more common in modern aerial photogrammetric flights, every localization will be accessible for visualization using several models, and there will be less concealed areas.
Few algorithms for generation of parallax are tested. After completion of sets from a dozen or so example models of interesting areas are gathered, there will be release. Authors are confident that stereo orthoimage may prove more useful for GIS users than true orthophotomap.

1. INTRODUCTION

The concept of stereo orthophoto technique published by Collins 44 years ago (Collins, 1968) quickly became a subject of research and implementation. A number of devices with 3D stereo orthophoto measurement capabilities have been built. Accuracy of those devices has been tested (Real et al 1974, Jachimski 1978, Kraus et al 1979) and possible application areas have been indicated (Błachut, 1971, 1976). However after about 10 years, further development of the stereo orthophoto technology had been discontinued, probably because of the occurring disadvantages, such as very large size of measuring devices or poor quality of available photographic materials. These disadvantages discouraged potential users, which would have been architects, geologists, foresters, topographers, etc. This slightly forgotten technique was reinstated in the 90s, when GIS had been already well developed (Sarjakoski, 1990, Baltsavias, 1996, Li et al 1996). In the last decade some visible attempts to return to the stereo orthophoto technique with a greater emphasis on GIS applications have been made(Li et al 2002, 2009, Wang, 2004, Chang et al 2008). While orthophotos have been firmly established in the GIS environment, stereo orthophotos are still scarcely used.

The purpose of this article is to present possibilities of broader use of the stereo orthophoto technology in GIS. According to the authors ,the original Collin's and Blachut's idea to introduce the stereo orthophoto to the wide range of users is worth reinstating. It could be achieved by strong technique implementation in the GIS technology.

2. STEREO ORTHOPHOTO PRINCIPLES

The term stereo orthophoto refers to the pair of images, where one of the images is a classic orthophoto and the other one is a quasi-orthophoto. This quasi-orthophoto is created from an adjacent image by introducing artificial longitudinal parallax during orthorectification process in order to achieve fully metrical 3D model. Created pair of images not only inherit the artificial parallax but residual parallax as well. This residual parallax is generated for the objects protruding from the terrain in the classical orthorectification process of two neighbouring aerial images.

Stereoscopic vision of the height differentiation of the terrain is possible because of the presence of the artificial parallax, while height of the objects protruding from the terrain – through the residual parallax. Objects protruding from the terrain and not being orthorectificated, such as buildings, chimneys, towers or trees are called vertical objects in the next parts of this article. There are some alternative versions of stereo orthophoto possible. One of them relies on stereopair creation based on only one photo however stereoscopic effects is achievable only for the terrain. Observation of two overlapping orthophotos without stereo mate component is another option, but stereoscopic effect in this case is limited to vertical objects visible on the flat terrain background.

The principles of “full version” of stereo orthophoto generation, which provides stereoscopy effect for both the terrain and vertical objects are presented in the figure 1. Upper part of the figure explains why, between orthophotos generated from left and right images residual parallax is formed for the vertical objects. The scheme of stereo mate generation is shown in the lower part of the figure. In the process of the right image orthorectification orthogonal projection is replaced by quasi-parallel projection of the terrain points.

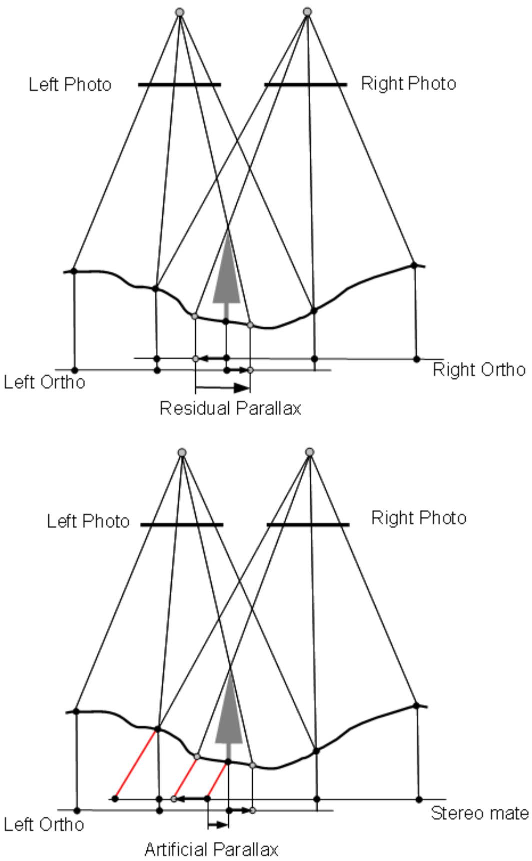

Figure 1. Principles of stereo orthophoto generation.

The mathematical function that links artificial parallaxes with the terrain elevation model could be linear, which corresponds with the slope parallel projection. However better results could be achieved by introducing logarithmic function into projection (Collins, 1970) as shown in the equation 1:

$$P = B \cdot \ln \frac{H}{H-h} \tag{1}$$

where P - artificial parallax,
B - base line of photograph,
H - flight height above the reference level,
h - terrain height/elevation above reference level.

Parallax calculation from equation 1 not only improves accuracy of stereo orthophoto height measurement but positively influences balance between the artificial and residual parallax with parallel projection and variable angle method (Li et al 2002).

Figure 1 presents situation, where area around the vertical object is relatively flat. In such case residual parallax calculated from the equation 2 is a good height indicator. However, if the object is located in mountainous terrain, especially at the top of the mountain or in the middle of the valley, then the residual parallax is distorted, what–introduces errors in vertical objects height determination. This explains worse accuracy of stereo orthophotos in mountainous terrains (Figure 2).

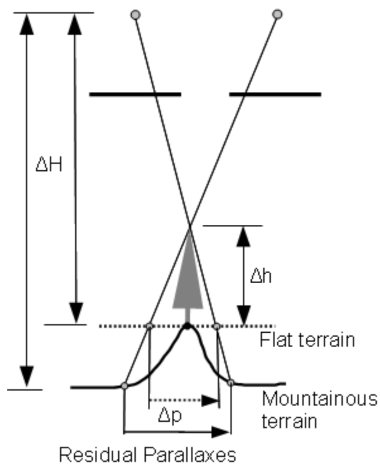

Figure 2. Residual parallax distortion for vertical objects in mountainous areas.

$$\Delta h = \frac{\Delta H \cdot \Delta p}{\Delta p + B \cdot \dfrac{c}{\Delta H}} \tag{2}$$

where Δh – height of object relative to its base,
Δp – residual parallax,
B – base line of photograph,
c – focal length,
ΔH – flight altitude above vertical object position.