CORRECTION OF RELIEF INVERSION IN IMAGES SERVED BY A WEB MAP SERVER

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ABSTRACT

The recognition and comprehension of 2D forms in cartography advised by graphic semiology [BER, 1967] and [BER1988] is restricted by continuous perceptive contrasts leading to the creation of a perceptive model of reality. The transgression of perceptive contrasts facilitates the creation of false images against which it is difficult to fight. Such is the case of optical illusions. When land relief is visualized, the situation of the light source is crucial for its correct comprehension. In vertical aerial photographs and in satellite images of territories located in the Northern Hemisphere, a relief inversion is often produced that must be analysed. A solution is described that may be implemented in a map server conformant with OGC, with elimination of the pseudo-relief, thereby helping the map reader to correctly understand the reality of the terrain.

INTRODUCTION

This study examines the circumstances wherein the pseudo-relief or relief inversion effect appears [PATT, 2004] in the images of the Northern Hemisphere territories, taken by airborne or satellite sensors. The forceful cognitive limitations imposed by perceptive contrasts are explained [BOS, 1984], and it is shown how human perception infers that zenithal images of terrains are lighted by a source located at the left upper corner of the support (for convenience we shall state in this study that the source is located NW of the support). Some method is explained to simply eliminate this pseudo-relief. It is shown how the incorporation of a layer with the DTM correctly lighted may crucially influence the perceptive modification of the relief, allowing the user to grasp the real terrain morphology. Finally, this solution has been integrated into a WMS (OGC). Finally, the huge change induced in perception is shown.

RELIEF VISUALIZATION

The use of contour lines for relief representation provides for knowledge of the height of each one of the points of the terrain represented (quantitative component) and the creation of a perceptive model of the reality of that terrain (qualitative component) for experienced map readers. While in order to know the height of any point of the terrain, the reader only needs a basic training, the total relief perception of that terrain based on contour lines (Fig 1a) is not always easy. The Digital Terrain Model (Fig. 1b) facilitates total comprehension of the relief and this comprehension does not involve any practical training. However, this system does not allow to know the point heights. Contour lines generate “a map for relief analysis” and with the shading model “a map for relief observation is obtained”. The final image (Fig. 1b), which is the blending of a contour line map with the shading model enables us to have both measure levels (quantitative and qualitative) at the same time. This is the most complete method in traditional topographic cartography on paper.

Figure 1(a)            Figure 1(b)            Figure 1(c)

Lately aerial photographs or terrain satellite images are been incorporated in maps as base cartography, in an attempt to provide the real impression of relief by means of that thematic layer. In some cases the conveniently geo-referenced actual photographic image has been used, with the addition of a lettering layer and a contour line layer, as a substitute for topographic cartography. As will be proven next, this leads to perceptive errors, especially in cartography of territories of the Northern Hemisphere, due to the creation of an inverse relief (Figure 2) developed by the mind of the reader when the light source is not located in the left upper part of the visualized image.
PERCEPTIVE CONTRASTS

Under this name are known those changes brought about in object perception even though the stimulus remains immutable [BERN, 2000]. This is due to the reciprocal interaction of objects or to the interaction of objects with the environment. Contrasts modify the perception of a number of visual variables (Figures 3-6) and in our particular case, the relief as well (Figure 7).

Figure 3. Contrast of shape: the figures (here circles and squares) lose their visual geometric essence due to the background interacting with them and changing them. The reader cannot correctly visualize the real shape even if he wants to.

Figure 4. Contrast of size: the perceptual size of the central circle (a) is seen changed due to the size of the surrounding circles. This is important for the design of sizes applicable in thematic cartography (b).

Figure 5. Contrast of value: The value of an object is changed by the surrounding values. In (a) all little central squares have the same value of grey. In (b) the central grey of both squares behind the bars has the same value.

Figure 6. Contrast of colour shade: The same shade is perceived as different due to the surrounding shade. a: J. Albers’ well known figure. b and c: two examples wherein the shade of the little central square tends to the shade opposite the one surrounding it.

Next figures show the perceptive strength visual contrasts have. That contrasts lead the reader to erroneously perceive printed reality. The relief inversion produced in an image when it is rotated 180° is displayed in the next example.
The effect of caved-in marks of the relief in figure 7(a) is caused by the fact that the perception assumes the light source to be located in the northwest of the image. In (b) the same image, rotated 180°, is displayed. The perception keeps on assuming that light comes from the NW (1) and the consequence of that is relief inversion [ROCK, 1984]. Likewise in (c) and (d) the same landscape is displayed with the light source in the NW and the SE. In (d) the light source has been placed in the SE, but the reader’s perception assumes a pseudo-relief corresponding to the real relief that would be obtained if the light source had been placed in the NW. Next, some transformations on a same object will be applied with the aim of studying the behaviour of perception in each one of them and reach conclusions.

1 For convenience the term “NW” will be used, in spite of the fact that “upper left part in relation to the reader” would be more correct, since “upper left” is where the reader’s perception assumes the light is coming from. “NW” is used as a matter simplification.

Shaded relief and induced perceptive contrasts

Relief obtained by shading is a way of esthetically, naturally representing topography in easy-to-read maps. In order to design a shading making its comprehension easy, a rule should be maintained, namely the terrain should always be lighted from the left upper corner of the map. [PATT, 2001]

In order to analyse the variations produced in perception due to the application of transformations, we will choose an image (Figure 8) wherein a relief may be perceived in accordance with the nature it represents: rivers naturally flow through the bottom of valleys.

In figure 9, the same terrain of figure 8 is displayed, though it is lighted from the SE. Our cognition alters the relief so that light will appear to come from the NW. The mountain in figure 8 has been transformed in a pit. Just by rotating this page 180°, the reader will verify that the reliefs get inverted again. It is clearly not easy to fight against this pseudo-image.

As noted above, the effects of two image transformations will be introduced and analysed:

- Rotation around the axis vertical to the image plane (Figures 10 and 11)
- Chromatic inversion of the grey value component (Figures 12 and 13)
Figure 10 shows the image of figure 8 after rotation of 180º. Perception offers an inverse relief of a figure in relation to the other one. The power of representation is such that in spite of the reader recognizing the tracing of the rivers and the impossibility of them flowing along dividing lines, the relief appears inverted and the reader has to make a huge effort to try to correctly comprehend the relief.

Figures 12 and 13 are the negatives of the images in figures 8 and 9. The result is also a relief inversion, the relief perception of figure 13 being correct. By comparing figure 8 with figure 13, the reliefs are equal but grey shadings are inverse.

Drawing conclusions from the previous figures, in the design process of the cartographic relief, attention shall be paid to the fact that in the majority of cases the reader assumes:

a.- that the source lighting a relief (on paper or on the screen), comes from a point located at the upper left part of the support (paper or monitor). In plain words, light comes from the NW corner.

b.- A printed relief lighted from the S tends to get inverted and to be erroneously interpreted.

c.- An erroneous relief may be correctly read by a 180º rotation or a grey shading inversion.

Some maps lighted from the south may be correctly perceived, but even so they are more difficult to read than the ones lighted from the north. Figures 14 and 15 [SR] reveals this fact:
Earth relief visualization in the Northern Hemisphere

As seen in figure 16, the Sun in the Northern Hemisphere is always located “towards the south”. Because of this location, aerial photographs or satellite images of the Northern Hemisphere light the southern sides of the mountains (sunny areas) while the northern sides are in the shadow (shady areas). If these images are used as a basis for map reference, wherein the rule is usually to place the north of the map in the highest part of the paper, maps will be obtained wherein it will be difficult to adequately perceive relief, especially in mountainous zones where the terrain shows very contrasted areas of light and shadow. The example shown in figure 2, an image of the Principality of Andorra, clearly shows this relief inversion in the Northern Hemisphere. We shall use this same instance to analyse the results in the search for a general solution applicable to colour graphic files. Contrariwise, in the Southern Hemisphere, as seen in figure 16, the Sun in its annual journey will always be “towards the north and aerial photographs and satellite images will be correctly perceived.

Possible solutions to the relief inversion effect in WMS

We shall carry out some transformations on the image of figure 2 to evaluate results and get a methodology.

Image rotation

The original image (figure 2) clearly showing a pseudo-relief, is rotated 180º, whereby a true relief is obtained (figure 17). The utilization of this image in a WMS is limited as follows:

a.- The map reader is used to see the north of the territory in the upper part of the map. It is difficult for the reader to understand “upside down” maps, even though the texts were placed in the correct reading position.

b.- In order to be able to interoperate with other servers, they should be also designed so that the north of the territory corresponded to the lower part of the map. Therefore, it does not appear to be a solution applicable to WMS.
Chromatic inversion of the image

Following the methodology used for figures 12 and 13, wherein the grey values were inverted, figure 18 shows an inversion of the colour shades and values carried out starting from figure 2. By getting the negative (figure 18) the values are inverted, the dark ones (shadows) becoming clear and vice versa. The relief we achieved is correct. However, the colour shading has been transformed in a not desirable direction. Now shading shall be modified without modifying the value. For that purpose we shall use a colour balance tool to manually adjust colour shading and try to match the general shading with the original one of fig. 2. The colour balance tool will be used such as the one shown in fig. 19.

The result (fig. 20) shows that though there is a chromatic proximity of the whole to the original and the relief perception is correct, there are semantic discrepancies with the original that are unacceptable, as for example:

a.- lakes switch from dark to clear.
b.- paths switch from clear (earth paths) to dark.
c.- Places without vegetation turn into places with much vegetation and viceversa.

This same process may be applied to closer images wherein the urban configuration may be visible (figures 21-24). As seen in figures 23 and 24, the negative consequences mentioned in the previous example become more noticeable since the urban configuration now appears emphasized by clear lines that do not help to comprehend its relief. Although the value inversion leads to a correct relief perception, a colour shading modification is not acceptable as it implies a change of meaning of the image zones. It is for this reason that other authors who have extensively used the Photoshop programme for relief improvement [PATT, 2001], have not followed this path.
Conflation of two layers: Shadow-model layer plus ortho-image layer
The application of shading to satellite images has been dealt with previously [RUD, 2000], but at the present time the target seems to be to make it extensive to WMS, so that the application process will become automatico.

Figure 25 Shadow-model of Peña del Rayo, Galbarruli, La Rioja (Spain). North is upper part of the image.

Figure 26 Ortho-photo of the previous area in the same relative position.

Figure 25 is the model of the relief provided by shading, wherein the light source has been placed in the left upper corner. The model clearly shows a mountain range covering the center of the image west to east. The center is occupied by an elevation known as Peña del Rayo. A river flows down east to west parallel to the north of the mountain range.

Figure 26 is the ortho-photograph of the same area showing us a relief inverse to the one observed in figure 25. What is a river on the left is a mountain range on the right. There is a hollow in the center corresponding to the chain of elevations of figure 25.

The methodology to be explained next consists of superimposing both layers providing one of them with a degree of transparency, with the aim of modifying the perception of the relief offered by the ortho-image, so as to give preponderance in the mixture to the relief offering the shadow-model.

There are already instances [PATT, 2002] contributed by some applications that have used the transparency capability of information layers to generate cartographic images wherein the relief contributes an important qualitative component of authenticity. Such is the case of the NSD Programme [NSD] that allows the creation of virtual spaces based on Digital Elevation Models to which the topographic map of the area is added or a superimposed virtual landscape is generated. (Figure 27).

Figure 27 Perception of relief (DTM) with the contribution of the topographic layer (left) and a hypsometry (right)[NSD]

We shall apply a variant of the “lighted relief” technique [PATT,2002] to combine the layers of figures 25 and 26, pursuing an automatic, simple and general method to be applied by the WMS, in order to generate a correct relief model.
The shadow-layer is placed over the ortho-photo (figure 28) using an application allowing transparencies, in our case Adobe Photoshop. As shading keeps on becoming transparent, the ortho-photo progressively gains relevance (figure 29) and the relief starts becoming inverted.

The application of a low degree of transparency to the shadow-layer, for example 20% (figure 29) results in images with a very good relief perception but with little ortho-image saturation. They look like a frozen landscape. The application of a high degree of transparency, as in figure 31, where an 80% transparency has been applied, results in images wherein the relief of the shadow-layer does not impose upon the relief of the ortho-photo.

It may be concluded that by placing the shadow-layer over the ortho-image layer and by applying to the shadow-layer a transparency of nearly 50%, an acceptable compromise result is achieved, as seen in figure 30, where a transparency of 40% has been applied to the shadow-model.

In order to correct the lack of colour saturation due to the influence of the shadow-model, a correction may be made through a contrast tool that may favour the compromise between correct relief and true photographic background. By means of a 50% transparency (figure 32), the photographic background becomes noticeable and the shadow model shows up with its intensity. By modifying the contrast (figure 33). The contrast may be changed without losing the perception of the relief that had been attained.
The comparison of the result (figure 34) between the original model and the final combined model allows to ensure a substantial improvement. The two small images on the left have given rise to the one on the right. In the latter, thanks to the shadow model, the relief is correctly perceived and the contribution of the ortho-photo allows identification of the human and forest features of the terrain.

APPLICATION TO A WMS

Map servers in the Internet are very much in use at present, not only by users skilled in geographic information matters, but also by plain citizens consulting geographic information. Providing an erroneous visualization of relief does not appear acceptable, especially in view of the influence the available map services in official organizations may and must have in school education.

WMS’ have the capability of providing transparency, superimposing and merging information layers, both raster and vectorial, of the visualized geographic areas. On this capability will be based the solution of this study case. As shown in figure 35 a WMS is utilized, enabling satellite or aerial ortho-images for visualization of the ortho-photo layer of a particular geographic aerea.
Figure 36 displays the enlargement of the visualized area in the WMS and the hydrographic layer has been superimposed (figure 37) so as to show beyond all doubts the relief inversion brought about by optical illusion. The shading of the relief and the hydrography has been visualized in a WMS (figure 38). Figure 39 is the merging of the ortho-photo layer and the relief shading produced in the map server (37+38).
Open Source MapServer [MapServer] software has been used as WMS server. In the MapServer configuration file, the available layers in the service are defined, following a certain order and transparency. In our case, it was set up so that the ortho-photo, with a 20% transparency, was under the shading layer, with a 60% transparency. This transparency of the shading layer allows visualization of the orthophoto, with the addition of an impression of relief contributed by that layer, while the ortho-photo was assigned a 20% transparency in order to tone down colour power. The result was achieved after several successive tests.

The inversion of layer arrangement, i.e. shading underneath and ortho-photo on top, does not provide an adequate result, due to the fact that the ortho-photo requires a high percentage of transparency to allow visualization of the shading located below, that has less chromatic power. An ergonomic solution in map servers is obtained when both layers (shadows and ortho-photos) are coupled, so that when the user activates the ortho-photo layer, the shading layer is activated at the same time. The map server must automatically take care of carrying out the merging of the two layers for each consultation.

Shading improves relief perception (figures 40 and 41) in those areas where the terrain is not rugged, such as is the southern half of the previous images. The existence of relief in areas where the ortho-photo does not provide it may be made evident, such as the extremely sharp ridges of the area on the east, as seen in figure 41, not evidenced in figure 40.
CONCLUSIONS

1.- The relief of aerial images of mountain terrains of the Northern Hemisphere undergo a perceptive inversion.  
2.- Perception, in the visualization of the relief of zenithal images, assumes that the light source is located at the left upper corner of the image.  
3.- If the light source is located in the lower part of the image, the perception inverts the relief with the aim of locating the light source on top.  
4.- By placing a semi-transparent layer with true shading relief over the layer provided by an aerial or satellite image, the semi-transparent layer may produce the vanishing of the inverse relief perception of the latter.  
5.- By using a map server providing transparency to the layers, the inverse relief may be turned into a true relief, just by placing the shading layer, with a certain degree of transparency, over the photographic image of the terrain.  
6.- Las soluciones más aconsejables son aquellas que se consiguen cuando se superponen las capas de ortofoto y la de sombreado con una transparencia y una saturación tal que permita visualizar la información de las capas superiores.  
7.- An ergonomic solution of the map servers (WMS) is obtained when both layers (shades and ortho-photo) are activated at the same time. The map server should take care of routinely carrying out the merging of these two layers for each consultation.  
8.- The result of the conflation of the two layers in a WMS is a less saturated image than the original ortho-image.  
9.- The original data remains stored without any treatment or modification, the conflation being carried out by the client or by the server.  
10.- The images obtained continue to have their geo-spatial reference.  
11.- The degree of transparency should be tested. It should be placed in the WMS by default to find the most adequate perception.

This study has been supported by a cooperation agreement between the National Geographic Institute of Spain (IGN) and the Universidad Politécnica of Madrid.

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