DIGITAL IMAGE DODGING IN DIGITAL ORTHOIMAGE PRODUCTION

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ABSTRACT

With the increase production and use of digital orthoimages, the radiometric quality of orthoimages has caught more attention then before. Digital orthoimages are often found to be distorted or unbalanced in brightness and/or contrast within individual images and/or among images. This is true especially for color orthoimages. We often see digital orthoimages with unbalance problems, such as fall-off of brightness in image corners, or one side of an image is lighter or darker than the opposite side of the image, or the contrast at the top of an image is different from the contrast at the bottom of the image. When such kinds of orthoimages are put together or mosaiced together, the radiometric mismatches along image edges will show up. The differences in brightness and/or contrast among neighboring orthoimages often make one part of an object in one orthoimage look totally different from the rest part of the object in a neighboring orthoimage, which in normal case should look exactly same. The unbalance problems make orthoimages not only look bad but also increase the difficulty for image interpretation and feature classification. Existing commercial image processing software can do little for the problems, because they always process all image pixels equally without any consideration about possible unbalance within the image. A software called ImageDodge was developed at Photo Science, Inc. (PSI) and has been effectively used to correct or dodge all the digital orthoimages produced since which had unbalanced brightness and/or contrast. This paper discusses the unbalance problems for digital orthoimages, the distribution patterns of unbalance and their mathematical modeling. The paper also introduces the algorithm used in ImageDodge and shows some orthoimages before and after being dodged.

1. INTRODUCTION

With the increase production and use of digital orthoimages, the radiometric quality of orthoimages has caught more attention then before [Knabenschuh, 1995]. The reason is that in many cases, produced orthoimages are found to be distorted or unbalanced in brightness and/or contrast within images and/or among images. This is true especially for color orthoimages. Here an unbalanced image is defined as any image which has an uneven or non-consistent brightness and/or contrast within the image itself. Most digital orthoimages are generated out of images scanned from aerial photography. We often see aerial photography with radiometric problems, such as fall-off of brightness in image corners, or one side of an image is lighter or darker than the opposite side of the image (see Fig. 1), or the contrast at the top of an image is different from the contrast at the bottom of the image. The problems mentioned above Any orthoimage generated out of those kinds of images will have the same radiometric problems as the original photography have. When such kind of orthoimages are put together or mosaiced together, the radiometric mismatches along image edges will show up. Within the mosaiced image, brightness and/or contrast can change abruptly across seamlines and sometimes can make entire mosaiced image look a striped image with light stripes and dark stripes. The differences in brightness and/or contrast among neighboring orthoimages often makes one part of an object in one orthoimage look totally different from the rest part of the object in a neighboring orthoimage, which in normal case should look exactly same. All those problems will make orthoimages not only look bad but also increase the difficulty for image interpretation and feature classification.

Unbalanced orthoimages have to be radiometrically corrected or dodged. But existing commercial software are almost helpless for resolving the problems we talk here. The reason is very clear: all of those commercial software assume that each image being processed is radiometrically balanced, i.e. the brightness and contrast within the image are consistent. When they change the brightness or contrast of an image, they change every pixel of the image equally without any discrimination. If the original image was unbalanced, then the processed image will still be unbalanced. Commercial image processing software works well to reduce radiometric difference among images, but to resolve the unbalance problems within individual images we have to look for something else.

Photo Science, Inc. (PSI) is a photogrammetry/mapping company. Each year we produce thousands of orthoimages, black/white and color. Through years of orthoimage production, we have seen various kinds of unbalanced images. About one year ago at PSI, we developed a digital image dodging software called ImageDodge to correct unbalanced orthoimages. This software can process black/white images and color images. The software utilizes a generic solution for the unbalance problems and we have successfully used it to correct all the orthoimages with unbalance problems produced since the software was developed. The success in developing and implementing ImageDodge enables PSI to produce high radiometric quality orthoimages.

In this paper, next section presents and discusses some most commonly seen radiometric unbalance patterns and their mathematical modeling. Third section introduces the algorithms used in ImageDodge and its working procedure. This section also shows some orthoimages before and after being dodged. Last section of the paper gives a conclusion and some thoughts about future development.

2. UNBALANCE PATTERNS AND THEIR MODELING

To develop a software for image dodging needs to know what kinds of unbalance problems are involved and whether they can be mathematically modeled. That is a describing and modeling process. After having seen and examined various kinds of unbalanced images, we have found that there are two general properties which can describe an unbalanced image: the distribution pattern of the unbalance and the mathematic model of the unbalance. The distribution pattern is a function of the position in an image. The distribution pattern of the unbalance can be directional or radial. For example, sometimes the unbalance can be along the diagonal direction of two opposite corners of an image, or in some other cases the unbalance has a circle kind distribution with fall-off at corners. Another property of the unbalance is its mathematical model. At different point of the image, the amount of unbalance or distortion is different and the change of the distortion can be linear or nonlinear.

In reality an unbalance distribution can be of any kind of pattern. Directional and circular patterns are just some generic description of a distribution. But from our experience, directional and radial unbalance distribution patterns are the most common patterns. By definition, directional patterns include vertical direction (top-down direction), horizontal direction (left-right direction), and diagonal direction (along the line connecting two opposite image corners), and radial pattern describes a circular shape distribution of the unbalance with the center of the circle inside or outside an image. The distribution pattern of an unbalanced image will determine the direction to which the image will be dodged. For instance, if the bottom of an image is lighter than its top, dodging process should increase brightness from image bottom to image top accordingly.

The mathematical modeling of unbalance is to determine what kind of distortion an unbalanced image follows, i.e. whether the distortion fits a linear model or non-linear model. And, if the distortion fits a non-linear model, then what is the order of the model and its magnitude. The model and its magnitude together will tell how much each image pixel should be adjusted. People have noticed that many things can cause unbalance in brightness and contrast for an image and among them found some major factors, such as sun angle, earth curvature for small scale imagery, camera corner fall-off and ground surface reflection properties. One example for sun angle effect is when ground surface is a specular reflector [Kiefer, 1994], such as water, different sun angles or altitudes can make same water look black in one image and totally white in another image, or make part of a water area dark and the rest water area bright within an image. For small scale imagery, earth curvature can cause a graduated change of brightness and contrast along the direction formed by image center and sun position [Hussain, 1991]. The problem caused by camera are usually at image corners forming a circular shape fall-off.

People have modeled some factors mentioned above. The detailed discussion of mathematical modeling is not in the scope of this paper, but the brightness mathematical models for three major factors can be briefly summarized as follows:

Sun angle and earth curvature: $\cos[\theta(I,J)]$, (1)

where θ is the angle between sun light incident direction and surface normal [Hussain, 1991] and is a function of image pixel coordinates.

Camera fall-off: $\cos^2[\alpha\,(I,J)]$, (2)

where α represents a angle and is a function of the image pixel position I and J.

Clearly, if all above factors show up in an image, then the unbalance model for the image will be non-linear.

3. ALGORITHMS AND RESULTS

There are two possible ways to develop dodging algorithms. The first way is to identify all factors involved in causing unbalance and then quantitatively model them. One may be able to quantitatively determine some factors, but it will be very difficult to determine all of them, because many random factors are also involved. The first way has its theoretical foundation, but practically it is very hard to implement. The other method is to establish a generic polynomial model for all factors, random or not. First order polynomial represents a linear model while the higher order polynomial describes non-linear model. The generic solution method is easy to be implemented and has been proven to be effective. ImageDodge developed at PSI uses the generic solution method and has been successfully used to process hundreds of orthoimages.

Because of the complexity of radiometric unbalance, it is very hard to find a set of parameters which is good for all images. For example, we often see that orthoimages for one project have different unbalance patterns, either because original aerial photos were taken at different times, or because orthoimages were generated out of different areas of original photos. In this kind of situation, images have to be processed on a one by one basis, instead of being processed in batch mode. Also, to process one image, you may have to try several times to get the best adjustment for brightness and contrast.

Two pairs of orthoimages are shown at the end of this paper. Figure 1. Shows a pair of images with unbalanced brightness and contrast. There is a mismatch between left image and right image. The left side of each of the two image is lighter than the right side. Figure 2. are the two same images after being dodged by ImageDodge. In this figure, it is hard to tell where the edges of the two images are.

4. CONCLUSION

With the increase production and use of orthoimages, people now are paying more attention than before to image radiometric quality. Because some problems which are not that noticeable in individual orthoimages are very apparent when orthoimages are mosaiced together. Radiometric unbalance in brightness and contrast within individual images is the biggest problem for image quality. Existing image processing software can reduce radiometric differences among images very effectively if the images themselves are internally balanced. But they can do little for internally unbalanced images. ImageDodge developed at PSI has been successfully used to process hundreds of orthoimages. But because the complexity of radiometric unbalance, it now runs only under a manual mode. The future research and development at PSI will be focusing on investigating whether and how the dodging process can be automated, especially on finding a way that can automatically and quantitatively determine the amount of distortion.

REFERENCE

Hussain, Z., 1991. Digital Image Processing. Ellis Horwood Limited, England, pp. 213-218.

Kiefer, L., 1994. Remote Sensing And Image Interpretation. Third Edtion. John Wiley & Sons, Inc., USA, pp. 13-20.

Knabenschuh, M., 1995. Radiometric correction of orthophoto data. International Journal for Geomatics, Vol.9, 10, pp.72-74.

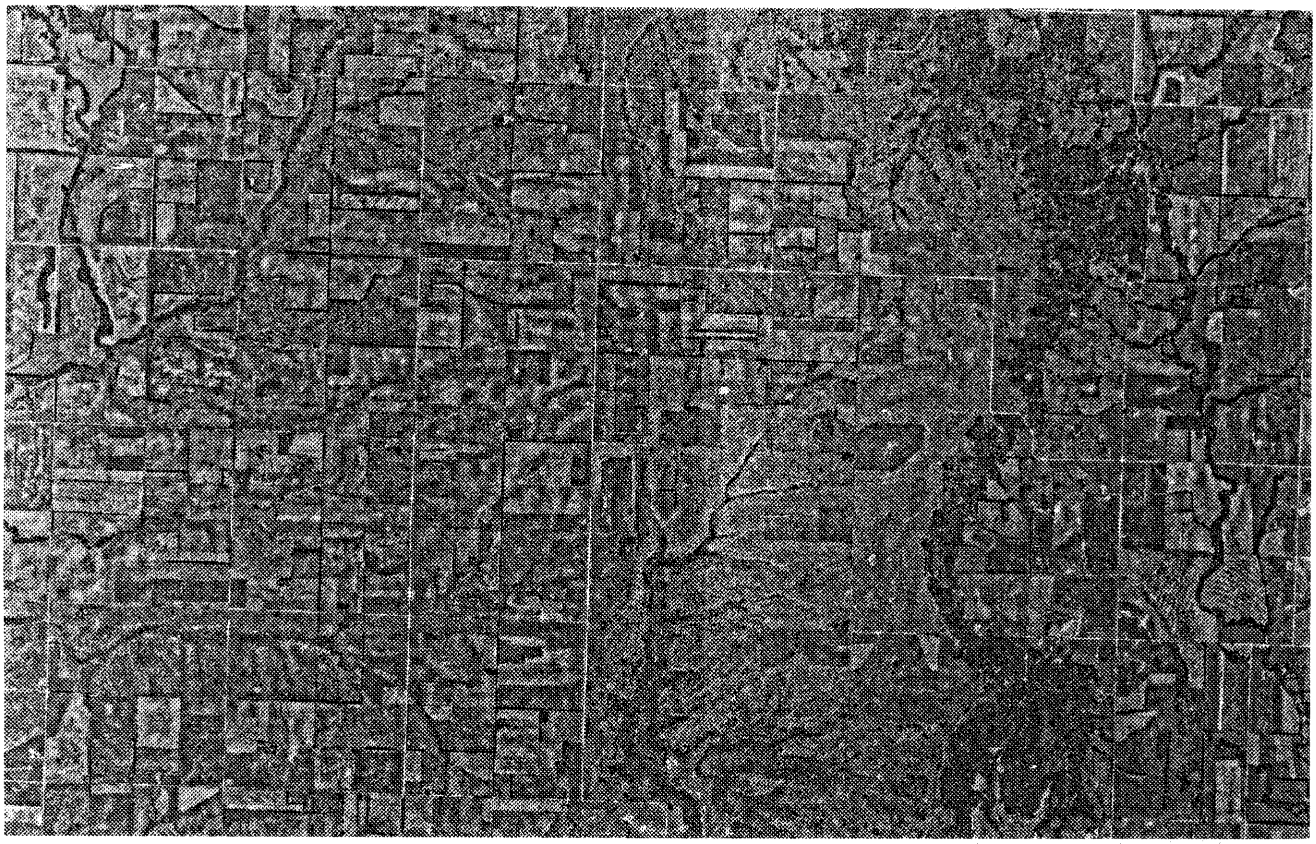

Figure 1. A pair of radiometrically unbalanced orthoimages. The left side of each of the two images is lighter than its right side.

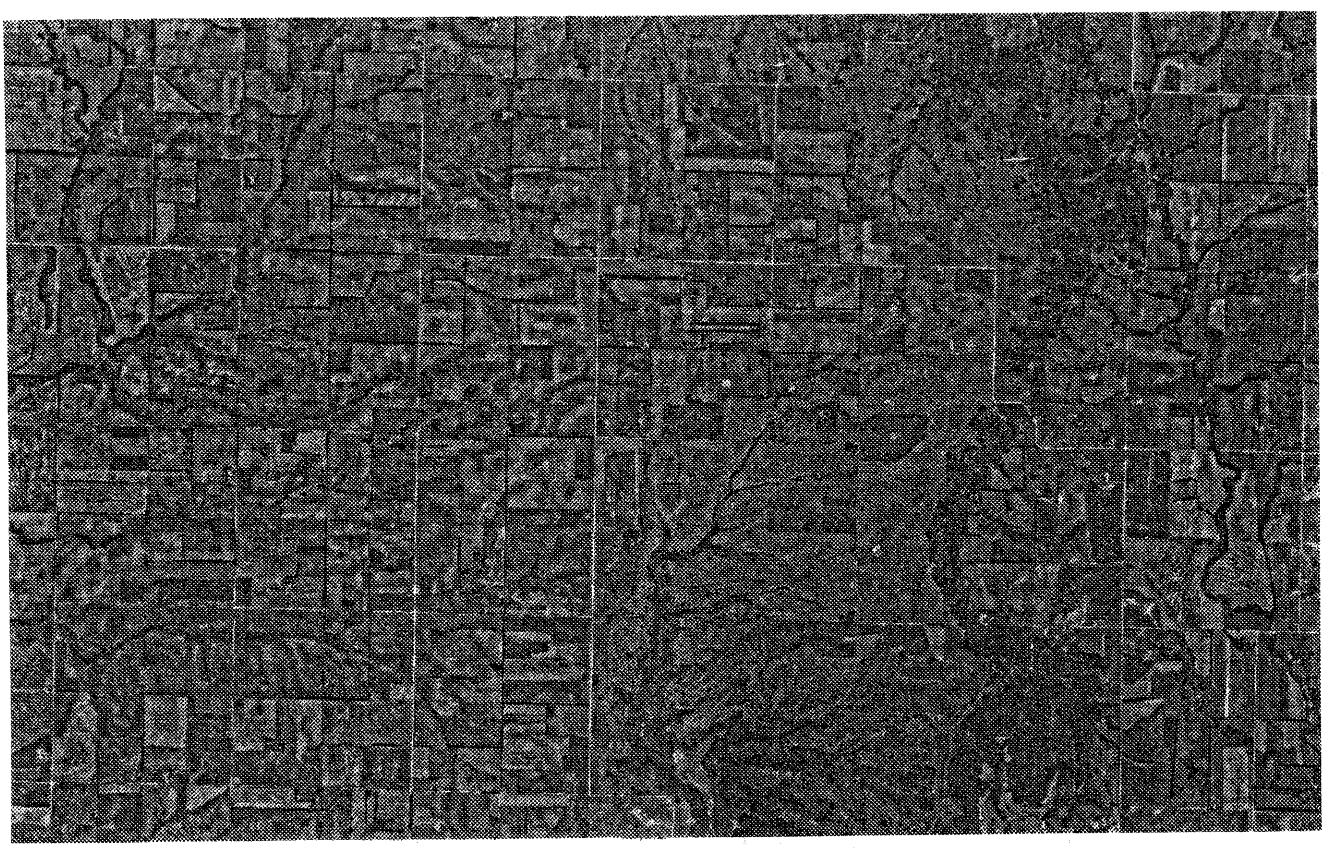

Figure 2. The same two images after being dodged by using ImageDodge.