PARALLAX ADJUSTMENT FOR REALISTIC 3D STEREO VIEWING OF A SINGLE REMOTE SENSING IMAGE

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ABSTRACT ... 3D stereoscopic viewing of large scale imagery, such as aerial photography and satellite images, needs different parallaxes relative to the display scale. For example, when a viewer sees a stereoscopic image of aerial photography, the optimal parallax of its zoom-in image should be smaller than that of its zoom-out. Therefore, relative parallax adjustment according to the display scale is required. Merely adjusting the spacing between stereo images is not appropriate because the depths of the whole image are either exaggerated or reduced entirely. This paper focuses on the improving stereoscopic viewing with a single remote sensing image and a digital surface model (DSM). We present the parallax adjustment technique to maximize the 3D realistic effect and the visual comfort. For remote sensing data, DSM height value can be regarded as disparity. There are two possible kinds of methods to adjust the relative parallax with a single image performance. One is the DSM compression technique: the other is an adjustment of the distance between the original image and its stereo-mate. In our approach, we carried out a test to evaluate the optimal distance between a single remote sensing image and its stereo-mate, relative to the viewing scale. Several synthetic stereo-mates according to certain viewing scale were created using a parallel projection model and their anaglyphs were estimated visually. The occlusion of the synthetic stereo-mate was restored by the inpainting method using the fields of experts (FoE) model. With the experiments using QuickBird imagery, we could obtain stereoscopic images with optimized parallax at varied display scales.

KEY WORDS: Parallax Adjustment, 3D Stereo Viewing, Stereomate, Remote Sensing Image, Anaglyph

1. INTRODUCTION

3D stereoscopic viewing is effective for various remote sensing applications such as image interpretation, tectonic analysis, landscape analysis, and sightseeing. Sometimes, there are problems in getting efficient stereography from a stereo pair of remotes sensing data. Between stereo pair images from a satellite or aircraft, differences of occlusion area and atmosphere are present due to the different acquisition angles and the time delay. Moreover it is hard to adjust disparity according to the viewer's binocular disparity or the viewing scale. Therefore the synthesis of stereomate can be made suitable for 3D viewing with a single image and disparity information. In computer vision, there has been a lot of researche about synthesizing stereomate from disparity-map (Fehn, 2003, 2004; Scharstein, 1996; Usery, 1993). For remote sensing images on a large scale, the Digital Elevation Model (DEM), or Digital Surface Model (DSM) can be used as a disparity-map (Bethel, 1991; Chang, 2006; O'Neill, 1998; Batson, 1976).

3D stereoscopic viewing of large scale imagery such as aerial photography and satellite images needs different parallaxes relative to the display scale. Therefore, relative parallax adjustment according to display scale is required. This paper focuses on the improving stereoscopic viewing through parallax adjustment with a single remote sensing image of high resolution and DSM to maximize the 3D realistic effect and visual comfort. The synthetic stereo-mates are created by a fictitious sensor model using parallel projection, and their occluded areas are restored by the inpainting method. Using anaglyphs, we compare and estimate the stereographic images which have different parallaxes and viewing scales

2. STEREO-MATE GENERATION OF HIGH RESOLUTION SATELLITE IMAGE

In order to create the stereo-mate from a single high resolution satellite imagery, the physical sensor model information is necessary. However, most high resolution satellites such as IKONOS and QuickBird provide only rational polynomial coefficients (RPC). When RPC is provided without any ephemeris data, directly extracting a satellite image physical sensor model is impossible. Therefore we used fictitious sensor modelling based on the parallel projection model (Chang, 2007). The entire process of stereo-mate generation is illustrated in Figures 1 and 2. First, imaginary ground control points (GCPs) are generated using the corrected RPC of the original single image. Then the parallel projection sensor model and its roll angle of the original single image are extracted by the imaginary GCPs.

An indirect method of the parallel projection model is herein employed to extract the physical sensor model. A satellite image is transformed to a parallel projection image, and then the physical sensor model is extracted in the form of parallel projection model. This process is shown in equations (1) and (2).

$$x = A_1X + A_2Y + A_3Z + A_4 \quad (1)$$

$$y_{P1} = \frac{A_5X + A_6Y + A_7Z + A_8}{1 + \frac{\tan\psi}{c}(A_5X + A_6Y + A_7Z + A_8)} \quad (2)$$

Where x=the coordinate along the flight trajectory

y_{P1}=the coordinate along the scanner direction before the perspective to parallel (PTP) transform

ψ = roll angel

c= principal distance

Using equation (1) and (2), we could get the parallel projection sensor model parameters $A_1 \sim A_8$, which means that parallel ray direction vector, the orientation of the image plane, the scale parameter and the translation parameter.

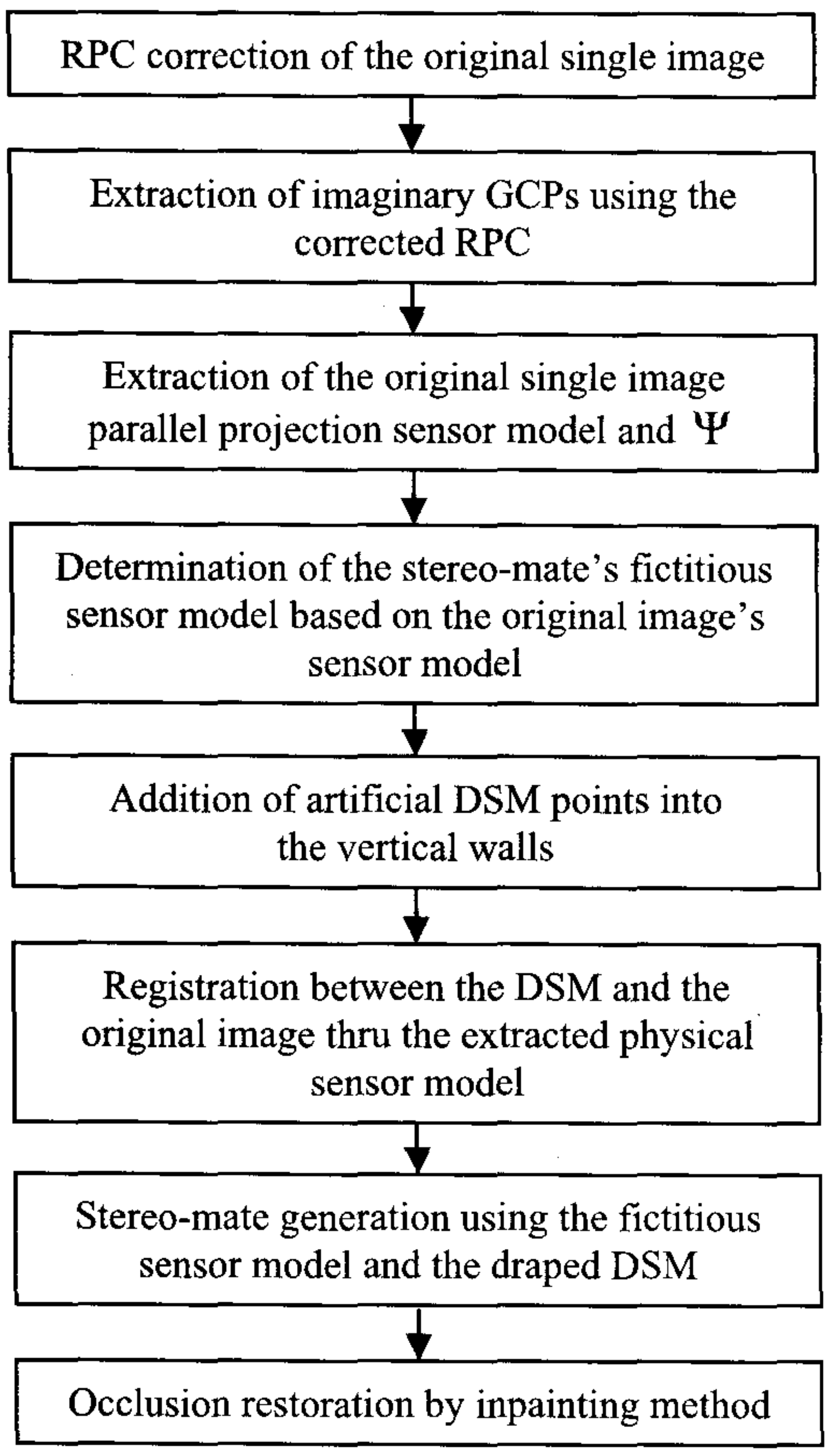

Figure 1. Workflow of the stereo-mage generation

After the original satellite image parallel projection parameters are extracted, they serve as the basis for determining a fictitious sensor model of the stereo-mate to reduce occlusion in the stereo-mate and to provide zero-y parallax. The original single image which is converted by PTP transform is projected onto the horizontal plane so that the x-parallax of the synthetic stereo pair becomes proportional to DSM height in the parallel projection model only when the synthetic pair is generated on the horizontal plane.

After the above projection, the parallel ray direction of the stereo-mate is determined using the intersection angle between the parallel ray vectors of the stereo-mate and the original image. The intersection angle is user-defined because it determines the x-parallax for stereo viewing. In our approach, we adjust the parallax by changing the intersection angle. The y-parallax is eliminated on the condition that the outer product of the parallel ray vector of the stereo-mate and the original image should also be normal on the epipolar plane.

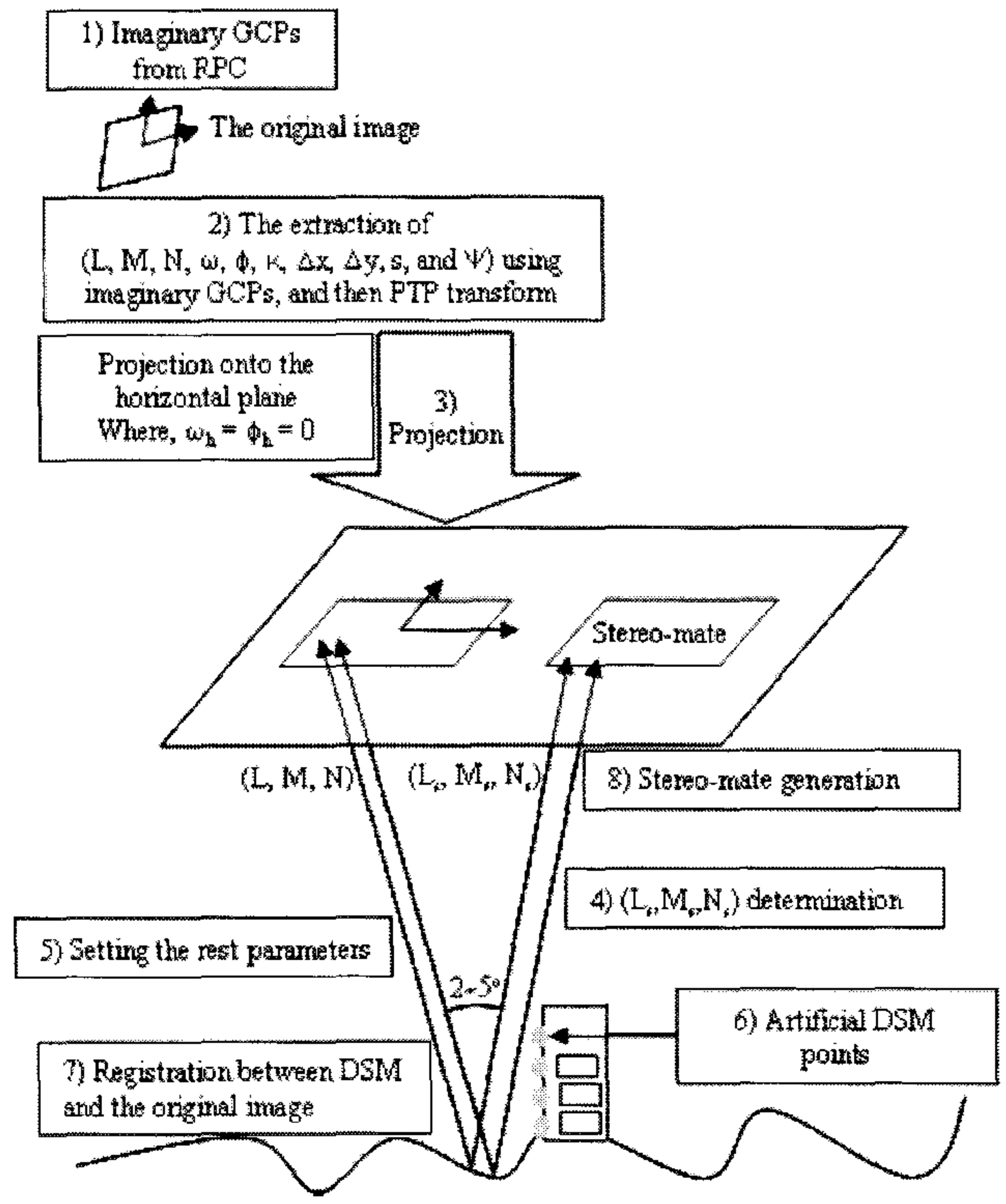

Figure 2. Stereo-mate generation process (Chang, 2007)

Artificial DSM points are added into the vertical walls and all DSM points are registered with the original image according to the extracted sensor model because they prevent the vertical wall area in the stereo-mate from being left blank and because they remove double-mapping in registering the DSM with the original image. Finally, the stereo-mate is synthesized by projecting the DSM registered with the original image onto the stereo-mate sensor model (Chang, 2006). In spite of adding artificial DSM points to reduce the occlusion, an occluded area may still exist. In order to restore this occlusion, we applied the inpainting method using the fields of experts (FoE) model (Roth, 2005). This algorithm has some advantages over other inpainting methods because it preserves more continuity of edge than other algorithms.

3. EXPERIMENTS

We generated various cases of stereo-mates with different intersection angles using a single QuickBird satellite image. Several viewing display scales were selected and the intersection angle for each scale was tested from 2° to 8°.

3.1 Experimental Data

The QuickBird panchromatic image used in this experiment covered Daejeon in Korea. The type of image was QuickBird Standard Ortho-ready, which had been processed only by radiometric correction. Its ground sampling distance was about 0.55m. The DSM was produced by light detection and ranging (LiDAR) data with 0.5m resolution.

3.2 Experimental Results

The following figures show the examples of our experimental test. Red-cyan glasses are necessary for stereo viewing. Figures 3 and 4 are anaglyphs of the original single image and the generated synthetic stereo-mate in a large display scale principally used for observing buildings. The image subset size is 800×800 pixels. Figures 3 and 4 are the results when the intersection angles are adjusted 2° and 8° respectively. Due to the vertical exaggeration being more enhanced in concert with the increase of parallax, the buildings in Figure 4 are shown higher than those in Figure 3. However, the parallax of Figure 3 is enough to generate a realistic 3D effect and to feel more comfortable visually. Figure 4 is dizzying to look at because of the exaggerated parallax and the excessive ghosting effect.

Figure 3. Stereo anaglyph at large scale (intersection angle: 2°)

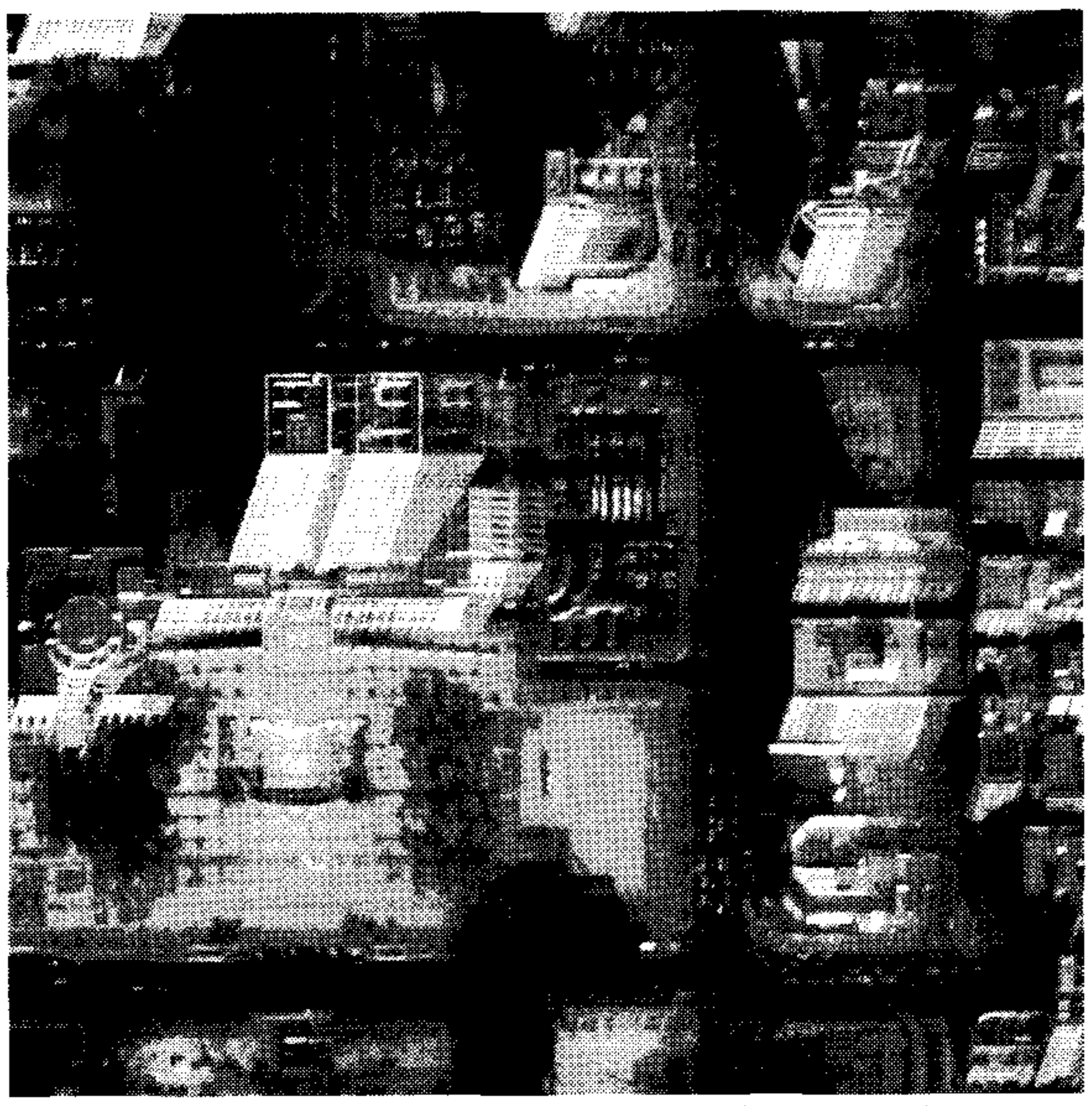

Figure 4. Stereo anaglyph at large scale (intersection angle: 8°)

Figures 5 and 6 show anaglyphs results in a smaller display scale principally intended for observing cityscapes. The subset image is 2500×2500 pixels. Figures 5 and 6 are the stereoscopic images when intersection angles are also adjusted 2° and 8° respectively, also. As shown in Figure 5, the ground relief can not be sufficiently felt. On the other hand, its 3D effect is more positive and comfortable to see visually.

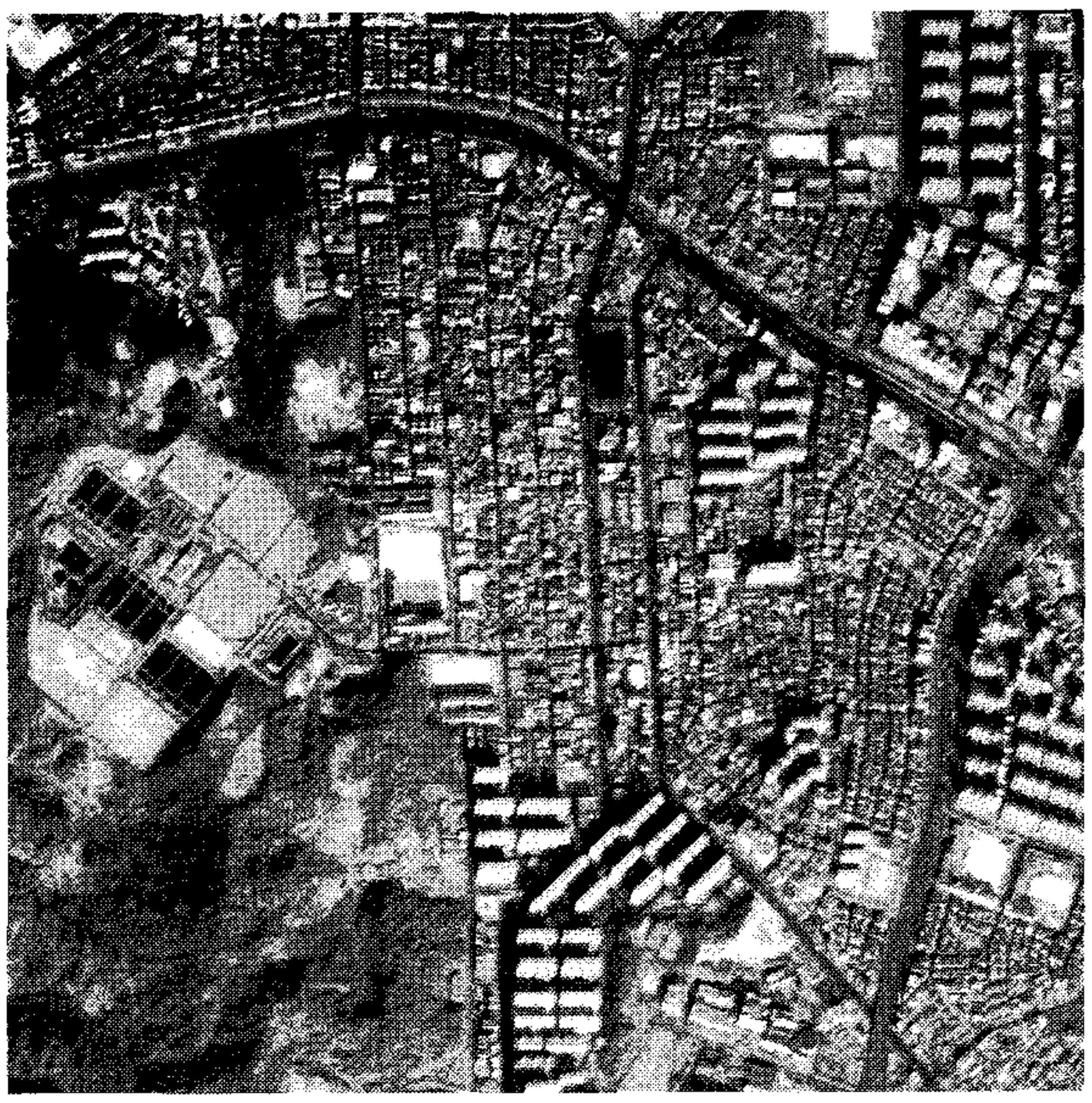

Figure 5. Stereo anaglyph at small scale (intersection angle: 2°)

Figure 6. Stereo anaglyph of small scale (intersection angle: 8°)

4. CONCLUSIONS

This research presented the improvement of the stereoscopic viewing through parallax adjustment with a single remote sensing image of high resolution and DSM to maximize the 3D realistic effect and the visual comfort. Several synthetic stereo-mates according to a certain viewing scale were created using a parallel projection model and their anaglyphs were estimated visually. With our experimental results, we could adjust the parallax of the stereoscopic image by assigning an intersection angle relative to the viewing display scale. The occlusion problem of the synthetic stereo-mate was resolved by means of the inpainting technique. In order to quantitate the amount of the intersection angle according to the viewing scale, it is necessary to analyze the physical meaning and to carry out additional tests of more specific cases. These are now the topics of our ongoing research.

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