Stereo-Photography with Hand Phone

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Abstract

A mobile phone (Hand Phone) is designed to display stereo images taken from a camera attached to it. Software of processing a stereo image pair to be displayed on the display panel of the phone is developed and a detachable viewing zone forming optics is installed for the stereoscopic image generation without moirés. Since the phone is operating only in the palm of the phone's owner, special cares needed in photographing the image pair are described.

Introduction

Hand phone (Mobile Phone) is now becoming a true multimedia center for internet, computer, telephone and television, and at the same time, there is also growing interests of displaying 3 dimensional(3-D) images on the phone for the purpose of gaming and new service developments.

Hand phone (HPh) is a hand held device, so its size cannot be bigger than that a user can hold onto his/her palm. In this sense, the size of its display panel can be hardly exceeding more than 3inchs. This size limitation also limits the available resolution of the panel to 240 x 320 (320 x 240). This resolution is not enough to display multiview images but to stereoscopic images. A stereo image pair for the stereoscopic image display can be obtained by the camera embedded on the HPh (HPh camera). Hence it will not be difficult to install a stereo-photographic function to HPh if a viewing zone forming optics (VZFO) and a software for processing the stereo image pair are implemented in the HPh.

Typical HPh cameras equipped with an objective of having f-number and focal length ranges of 2.5 - 4.5 and 4 – 12mm, respectively, and an image sensor of having size and resolution ranges of 1/7 – 1/2.5 inches and 1- 5 Mega pixel, respectively. As the resolution increases, either the pixel size should be increased or the f-number be reduced to overcome diffraction effect. The cameras of having these characteristics can focus a few ㎝ to infinity and have the field of view angle in the range 17° to 100°. The image sensor for the cameras is usually CMOS array for low power consumption and low cost. But it is noisier and has lower sensitivity than CCD. Furthermore, its uneven sensitivity and the plastic objective

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make the camera not for serious photographers but for fun makers. Hence stereo-photography with HPh is also for fun creating.

Taking a stereo image pair with HPh camera is one of difficult task because of the instability of hand movement. The instability can result many critical differences other than parallax between left and right view images in the pair. If these differences are exceeding the permitted values, the pair cannot be fused.

In this paper, the conditions of taking a stereo image pair which can be fused as a 3-D image, with hand phone photography and processing the pair to be displayed without moirés are described. And also installing detachable viewing zone forming optics in the hand phone is introduced.

2. Taking Stereo Image Pair with Hand Phone

When taking a stereo image pair with a camera, care should be given to make no other difference except parallax be involved. Since the relative changes in camera distance and position for left and right images will reduce the probability of fusing the images as a 3-D image, the camera position should be kept the same way except shifting along the same horizontal line and viewing angle adjusting when it is necessary. Two typical camera arrangements for taking multiview images for 3-D image generation are parallel and radial (toed-in) [1]. The parallel arrangement is referring to the case when all component cameras in a multiview camera array have their optical axes parallel to each other. In this arrangement, the part of the object, which is in the common field of view of all the component cameras, can only be viewed as a 3-D image. This arrangement is somewhat immune to geometrical distortions such as nonlinearity and keystone [2] but it is difficult to align. For the case of the radial arrangement, the optical axes of all component cameras in the multiview camera array are converged to a reference point with the same radius of curvature. Hence aligning the component cameras is relatively easier than the parallel because the cameras are angularly aligned by fixing the reference point to their view finder centers. The reference point makes the aligning easy but it is very vulnerable to the geometrical distortions [3]. Between these two arrangements, the radial is more appropriate for HPh photography because it provides the reference point. To take a stereo image pair with a HPh, the parallel arrangement allows shifting the HPh just a required distance along a horizontal line. But the shifting also shifts the object image position in the view finder accordingly. This makes the visual comparison of the object image position difficult. Furthermore, small changes in photographing distance and camera position in the process of shifting can result unacceptable differences between left and right images, especially when the object is in a short distance because the camera has a very short focal length. The radial arrangement will make the comparison easier because it can locate the object in the center of the view finder. The optimum distance of camera shifting in horizontal direction in the radial arrangement is approximated by the experiment. It turns about $1/30^{th}$

of the photographic distance for the case of a HP iPAQ rw6100 series pocket PC. Fig. 1 shows the effect of the base distance between camera positions for left and right images for the case when the distance between camera and object is 21 ㎝. It turns that for the case of the base distance is 5 ㎜, the parallax difference is too small to provide a recognizable depth, except in the handle portion. For 10 ㎜, the entire cup provides a recognizable depth. For 15 and 20 ㎜, the parallaxes in the handle part are too big to fuse. The same result is obtained with other objects.

Fig. 1. Combined Left and Right Images for Different Base distances
When the distance between HPh camera and object is 21cm

3. Allowable Differences between Left and Light Eye Images

The distortions in the stereoscopic images are derived from many reasons [4] but mainly caused by the differences between left and right eye images. The differences will be counted by image characteristics such as color, brightness, resolution, noise and geometrical shape such as magnification, keystone, linearity, image center shift relative to each other in both vertical and horizontal directions and image rotation relative to each other. In the HPh photography, the characteristic differences will not likely to occur because the same camera is used for both left and right images. The difference will come from the geometric shape because the camera is moved by hand for the images. It is typical that the radial arrangement is more subject to the geometrical shape difference than the parallel because the focused object planes of left and right eye images are different for the radial [5]. The main distortion derived by the object plane difference is the keystone distortion. The distortion is caused by y -axis value differences between corresponding points in left and right eye images, and nonlinear magnification of images in x -axis direction. These differences make the images have the shape of a trapezoidal and mathematical fusing of left and right eye images impossible. But viewers' eyes can fuse the images as a 3-D image until the differences are within a fusing limit, though a perspective distortion, i.e., a distortion in depth-wise is laden to the 3-D image. It has been known that the distortion can be eliminated by modifying the images to satisfy the following relationships [6].

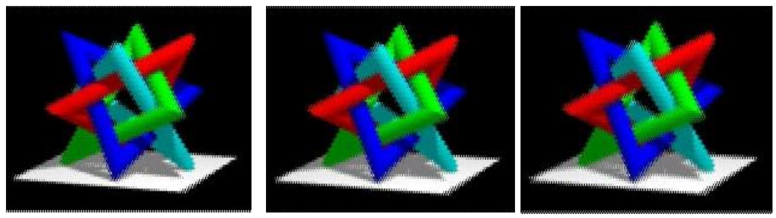
$$\frac{\sin\varphi_C}{\sin\varphi_P} = m\frac{z_C}{z_P} \text{ and } z_P^2 = mpz_C^2 / c \tag{1}$$

where, φ_C (φ_P), z_C (z_P), m, c and p are the half of left and right camera (projector) crossing angle, the camera (projector) distance from the focused plane parallel to the plane containing aperture centers of left and right cameras (projectors)screen, the size ratio of projected image to photographed image, and base distance between left and right cameras (projectors), respectively. The relationships in Eq. 1 result that the image projected to viewers eyes in radial photographic and projecting geometry becomes the same as that in parallel photographic and projecting geometry.

The permissible magnification difference is 5%. This difference indicates that the image size differences of 8 pixels (320 X 0.05/2 for top and bottom) in vertical and 6 in horizontal direction are allowed for HPh camera, in the display point of view. When object distance is far great than the focal length of the objective of a camera, the image of the object is appeared in the focal plane of the camera, i.e., the image magnification becomes inversely proportional to the object distance. This is the case for HPh camera because it has a very short focal length. When the object distance for left eye image is a, the permissible distance range for right eye image is calculated as $20a/21 \sim 20a/19$. If a equals to 1m, the range becomes 952 ~ 1053㎜. It allows about 10㎝ room to move around. But when a becomes 10㎝, the room is reduced to 1㎝. This room will be too small to keep the range. So it would be better to choose a as big as possible in stereo photography with HPh camera.

The allowable vertical direction shift between left and right images turned out to be 3 pixels of LCD display in the rw6100, which has a pixel pitch of 180㎛. Fig. 2 shows the combined images of left and right images for the case when left image is vertically shifted 2, 3 and 4 pixels. When the shift is 4 pixels, two images are hardly fused. It means that 3 pixels are the fusing limit. The pixel number is just a half of the number from the magnification difference. This indicates that when the 5% magnification is allowed only when the centers of two images are matched. When the image centers are not matched, the allowable magnification difference will be smaller. Fig. 3 shows the combined images of left and right images for the case when left image is rotated 4, 5 and 6 degrees by pivoting its center. The images are still fused up to 5 degrees. This angle is equivalent to 9 pixels shift of left image to the vertical direction at the left and right ends of the image. Since the animated image is extended only 2/3 of the image area, the actual image shift is approximated as 6 pixels. This result is consistent with the previous results. These results inform that matching the image centers of left and right images is important to extend the fusion range of the images. Since centering of the images is required in the radial, the radial will be more convenient in

HPh stereo photography than the parallel.



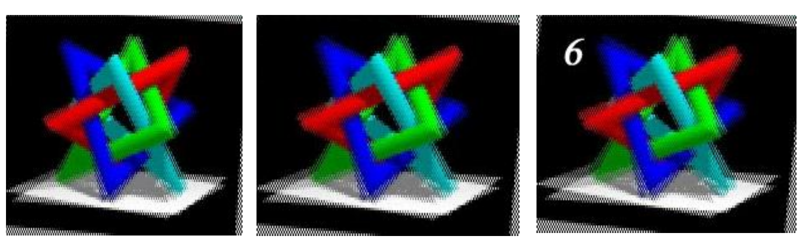
2 Pixels 3 Pixels 4 Pixels

Fig. 2. combined images of left and right images when the center of left image is shifted vertically to 2, 3 and 4 pixels

The resolvable depth in stereo photography can be calculated by the following relationship [7];

$$N = \frac{2t\sqrt{s^2 - (\frac{2.44\lambda F}{D})^2}}{sD} \qquad (2)$$

where N, t, s, D, λ and F are a number of resolvable depth, camera distance, pixel size of a camera, objective aperture diameter and focal length of the camera, and wavelength, respectively. For the case of HPh, when $t = 3cm$ (the photographic distance is assumed as 1m), $s = 4.5\mu m$, $D = 3.2mm$ and $F = 8mm$, N is calculated as 15.8, 12.5 and 2.5 for $\lambda = 0.4$, 0.55 and 0.7 μm, respectively. Since the N numbers cover almost entire distance range in the HPh, the depth resolution of HPh photography will be very poor. The depth resolution will be further reduced as the resolution of the camera increases. The increasing resolution will reduce each pixel size and consequently the value in the root of Eq. 2 becomes smaller. As a result, the camera's depth resolution is reduced and sensible spectral range can be reduced due to the diffraction effect.



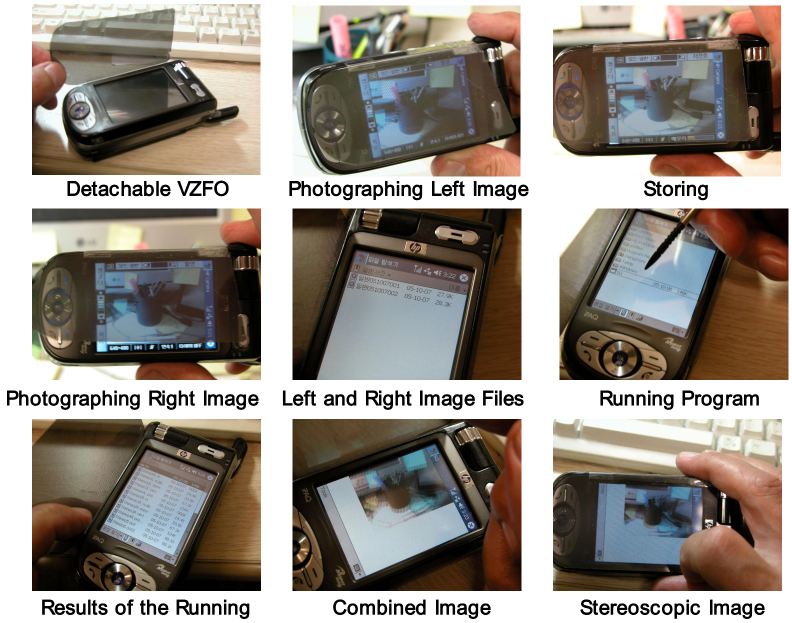
4° 5° 6°

Fig. 3. Combined images of left and right images when left image is rotated 4°, 5° and 6° in CCW direction.

4. Processing and Displaying Stereo Image Pair

To display the stereoscopic image pair taken by a HPh without moirés, the image pair has to go through several image processing steps [8]. These steps are including step-wise shifting each image line of each view image, combining the pair and stretching the combined image for display. For these processing, a software is designed with using Embedded Visual C++ 4.0 (VCCE) in the desk top PC which is equipped with VCCE IDE(Integrated Development Environment). VCCE IDE is obtained through internet. The VCCE can create and debug application softwares for devices running Windows CE and is compatible with Pocket PC. The rw6100 is working under the Windows CE environment. Since Windows CE cannot run all Windows XP programming services, it requires more time in developing software than Windows XP. To install the software, desk top PC or notebook should equip with VCCE IDE.

For the image display, the executable version of the processing software is transferred to the HPh through the USB port. In the transferring, the HPh should equip with Active Sync. This active Sync is basic feature of the HPh. The version requires about 150 Kbytes memory. In running the version, some additional dynamic data buffers are assigned in the operative memory to process images. The buffer size depends on the sizes of original images and the screen. When taking a photograph, the rw6100 automatically assigns a file name xxx.jpeg. Then in the running time, the software is taking two most recent image files and recognizes the latest file as right image and the other left image. After processing, the software creates a combined image of left and right images with images created at each step of the image processing. To view the stereoscopic image, it is only necessary to attach a viewing zone forming optics. Fig. 4 shows the process of taking stereo photograph, image processing and displaying. For the display, a detachable parallax barrier is used in the HPh. The barrier is attached only when displaying 3-D image. Since some HPhs are equipped with touch panel, a firmly attached viewing zone forming optics on the top of the display panel will reduce the touch panel sensitivity. The detachable structure will not interfere with the touch panel and allow 2-D/3-D switchable.

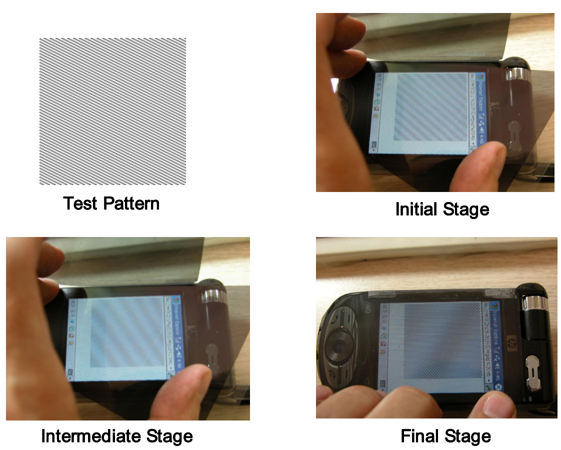


Detachable VZFO | Photographing Left Image | Storing
Photographing Right Image | Left and Right Image Files | Running Program
Results of the Running | Combined Image | Stereoscopic Image

Fig. 4 Stereo Photography

5. Aligning Procedure of Viewing Zone Forming Optics on HPh panel

To display clear and good depth sensed 3-D images, the viewing zone forming optics should be aligned properly on the display panels of all 3-D imaging systems. The alignment should also be done for the HPh. This alignment is performed with use of a linear aligning pattern as shown in Fig. 5. The pattern is consisted of periodic slanted lines.



Test Pattern | Initial Stage
Intermediate Stage | Final Stage

Fig. 5 Aligning Procedure of Optical Plate

The slanting amount and period should be the same as those of the parallax barrier. The slanting angle is related with moirés appearing in the HPh when the viewing zone forming optics is installed. The initial stage of alignment is displaying the pattern on the display panel of the HPh and overlapping the viewing zone forming optics on it. In this case, it is typical to have a moiré pattern. The period of the pattern represents the degree of alignment. The period becomes smaller, as the degree of misalignment increases. Hence the aligning process is making the period as big as possible so that no pattern appear. Fig. 5 shows the aligning stages. It is shown that the period becomes bigger as the completion of the alignment nearer. The viewing zone forming optics should be fixed to the position corresponding to that from the final stage of the alignment.

Fig. 6 shows several combined pictures taken by rw6100 HPh camera. The quality of the stereo images is different for different objects: Most of them reveal a recognizable depth sense but matching the left and right image is a hard problem, though a lot of practice had been done and a marker is used in photographing images. Another serious problem in stereo photography is the brightness of the HPh. It is simply not enough to create a good depth sense.

Fig. 6 Several Combined Pictures by Stereo- Photography

Conclusions

Radial camera arrangement is better for the Stereo photography with a hand phone to obtain a matched stereo image pair. But it is still hard to obtain the matched stereo image pair though the photography provides stereoscopic images with reasonable depth sense. The low brightness of the hand phone further aggravates the depth sense with the photography. For the better photography with the hand phone, it is necessary to design a software which will do a necessary adjustment the stereo image pair to be matched together. Furthermore, an electronic switch needs to be installed to the hand phone to increase brightness for the period of 3 dimensional image displays.

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