

Development of Image Distortion Correction Software for Underwater Photographs

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ABSTRACT

A large quantity of various still and video images are generated in underwater archeological sites and research labs for record keeping and dimensional analysis. A variety of image capturing devices including underwater cameras are used. It is well known that underwater photographs are distorted due to the difference in refractive indices of air and (fresh or salt) water. Due to the lack of convenient image processing software capable of underwater image distortion correction, distorted photographic images are frequently used in various reports.

We have conducted experimental studies on underwater photographic distortion as a function of geometry and distance between the window separating (clear or salt) water and a camera. Based on the simulating experimental photographing results, we developed distortion correction (compensation) algorithm for underwater photographic images. The newly developed function is added to the unified image processing software (PicMan from WaferMasters, Inc.) for convenient usage in underwater archaeological sites with ordinary notebook PCs. The unified image processing software, PicMan, can support various digital image formats (such as BMP, JPG, PNG, GIF, TIF, DM3, MOV, MP4, AVI, WMV etc.).

In this paper, a newly added function for underwater image distortion correction (compensation) to the unified image processing software will be introduced. It will be demonstrated using a few digital photographic images from a laboratory simulating underwater conditions and underwater archaeological studies.

Key words: Underwater Photography, Image Distortion, Distortion Correction, Image Processing Software

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INTRODUCTION

Underwater photography is essential for underwater surveillance and excavations. Water environments can vary over a wide range in terms of depth (water pressure), current, tidal flow, wave, wind, temperature, visibility, obstructions and so on. Heavy equipment and experienced diver(s), with supervision, are often required. Unlike photography on land, in air, it is difficult to set

up desired photography conditions under water. We are often forced to take photos under imperfect conditions and work with less desirable photos. In turbid water with high waves and/or fast tidal currents, as found in the Yellow Sea, we are forced to use a wide angle curvilinear lens or a fisheye lens with dome port to capture wide areal photographic images with barrel distortion (National Research Institute of Maritime Cultural Heritage of Korea, 2010 National Research Institute of Maritime Cultural Heritage of Korea, 2011).

Fisheye lenses were originally designed to photograph the sky with no straight lines, such as the horizon, because it will significantly distort the photographic image away from the center of the lens (or optical axis). However, more can be squeezed into the image, at the cost of distortion. Any straight lines and objects will be distorted and result in awkward looking images. This can also be used for capturing underwater scenes because very few natural straight lines exist underwater. However, underwater excavation sites often use artificial grid lines to segment areas and record the location of artifacts at the excavation site. The gridlines usually appear to be barrel shaped grids and make the estimation of exact locations and true shapes of artifacts from the distorted images difficult. Development of user-friendly and convenient image distortion correction software for combinations of various types of lenses and ports is desired.

In this paper, a newly added function for underwater image distortion correction (compensation) to the unified image processing software is introduced and demonstrated. We have used digital photographic images from our laboratory to simulate various underwater conditions and underwater archaeological studies. In addition, archived underwater photographs, were taken of (two Taean Mado shipwreck sites) in the Yellow Sea from 2008 to 2010 at archeological excavation sites using a fisheye lens with a matching dome port (National Research Institute of Maritime Cultural Heritage of Korea, 2010 National Research Institute of Maritime Cultural Heritage of Korea, 2011).

TYPES OF DISTORTION

The sources of image distortion in underwater photography are differences in refractive indices between media (air and water) as well as geometric configurations and shapes of viewports relative to the imaging device (camera) (Reef2Reef, 2021, HyperPhysics, 2021). There are two major types of image distortions; pincushion distortion and barrel distortion. The pincushion distortion occurs when a regular lens is used with a flat port. The barrel distortion occurs when wide angle view lens or fisheye lens are used with a dome port. The other combinations, such as a regular lens with dome port and a wide view angle lens (or a fisheye lens) with a flat port are possible, but there is no reason to make image distortion even more complex. The simple pincushion and barrel distortions are symmetric radial distortions in theory and fairly easy to correct by using a simple quadratic compensation formula. However, slight mis-orientation or shift in optical axis of camera and the viewport add complexity. Slight misalignment between focal points, between dome port and camera focal points, can also add additional complexity in image distortion. In this case, image distortion cannot be corrected by simple quadratic correction formulas (Jung et al., 2021, Wei et al, 2012, Xu, 2019, Meena et al, 2016). We have to add additional terms to properly correct the complex image distortions.

Figure 1 shows typical underwater photographs with (a) pincushion distortion and (b) barrel distortion. Photographs were taken using (a) a regular lens with a flat view port and (b) a fisheye lens with a dome port. The frame sizes and aspect ratios are different due to the difference in make

and models of cameras used in this experiment. They all looked like simple, symmetrical radially distorted images. In reality, they are radially distorted images with significant complexity.

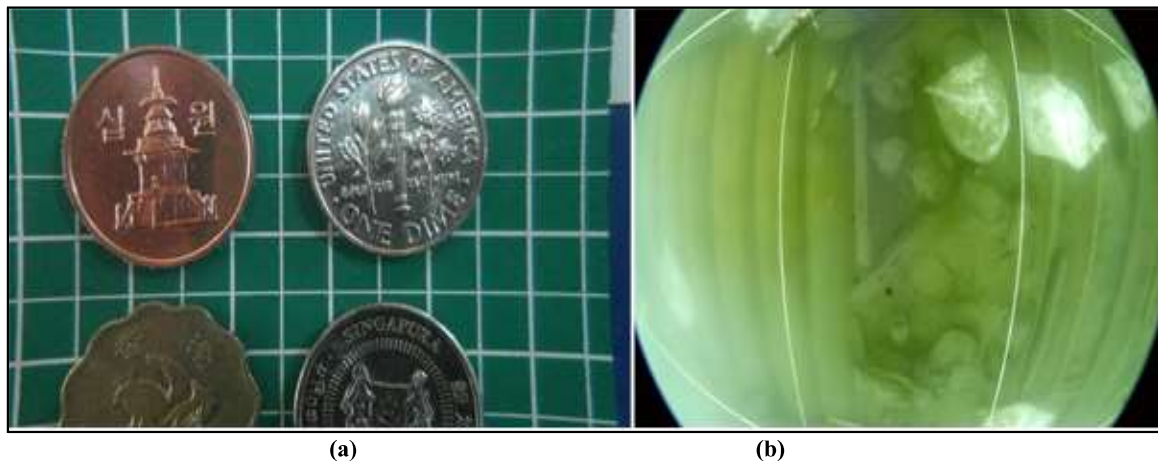


Figure 1: Photographs with (a) pincushion distortion taken using a regular lens with a flat view port and (b) barrel distortion taken using a fisheye lens with a dome port.

DISTORTION CORRECTION

Figure 2 shows the radially corrected images of Figure 1 (a) and (b). As seen from the Figure 2, the originally straight lines were still slightly distorted. In real underwater excavation sites, other than grid marking lines and manmade artifacts, there are not many objects exhibits straight lines. Thus, the small distortions left in the photographs are barely noticeable (Figure 3). For photographing underwater sceneries, including large objects such as sharks and coral reefs, photographers often intentionally choose a fisheye lens with a dome port knowing that the resulting photographs are heavily distorted towards the edges of the frame, and even blind spots at the four corners of the frame.

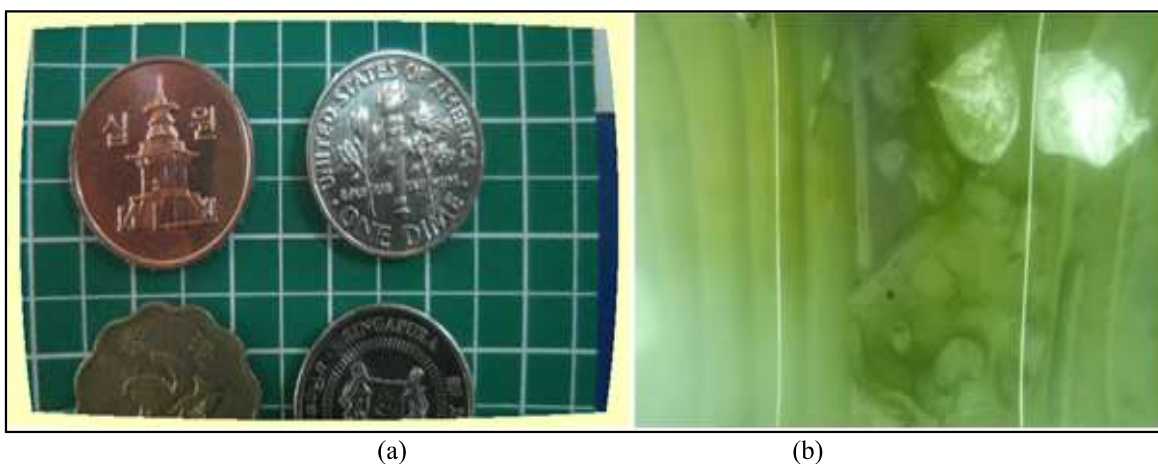


Figure 2: Photographs after simple radial distortion correction. (a) pincushion distortion taken using a regular lens with a flat view port and (b) barrel distortion taken using a fisheye lens with a dome port.

For mapping underwater excavation sites, it is desirable to have undistorted photographic images to generate site maps by combining multiple photographs covering a limited area. In turbid waters with very limited sight, such as in the Yellow Sea, it is almost impossible to take wide area photographs using a regular lens with a dome port. We have no choice other than using a fisheye lens with a dome port. Clearly, more accurate distortion correction capability is needed.

In addition, in the case of cropped photographs in publications, reports, from unknown sources and/or archived photographs without detailed photographing equipment and conditions, it is not possible to correct distortion by applying radial distortion correction formula because the center of a cropped photograph is different from the center of the original photograph. Additional degrees of freedom for compensating optical axis misalignment and offsets must be adopted into new image distortion correction software.

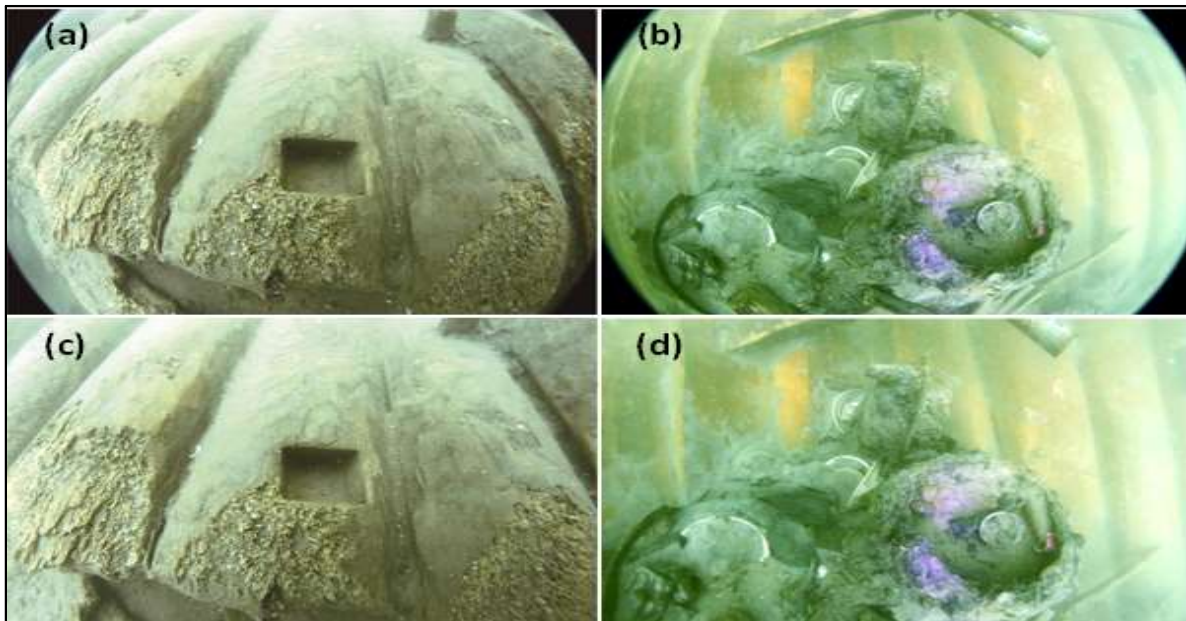


Figure 3: Photographs before and after simple radial distortion correction. (a), (b): original photographs with barrel distortion taken using a fisheye lens with a dome port and (c), (d): after simple radial distortion correction.

SOFTWARE DEVELOPMENT

To fulfill this requirement, we developed new software with optical misalignment and offset compensation features. The new function is added to a universal image processing/analysis software called PicMan from WaferMasters, Inc. (Kim et al., 2019, Yoo et al., 2019, Yoo and Yoo, 2021, Kim et al., 2019, Lee and Wi, 2021) Figure 4 shows fully compensated images of Figure 1. Radial distortion and spatial offset in horizontal and vertical directions can be independently compensated for achieving optimally straightened images. The same distortion correction setting can be memorized for processing subsequent images. Image distortion correction can be done by one image at a time or batch to batch processing. Distortion corrected images are either manually or automatically saved with new file names. Video files from the same recording conditions can also be processed and distortion corrected video files can be saved as a new video file. Initial reports on

underwater photographic image distortion compensation using PicMan have been reported elsewhere (Jung et al., 2021).

Screenshot images of Image Processing/Analysis Software (PicMan, WaferMasters, Inc.) used in this study after distortion correction and a popup window for image distortion correction are shown in Figure 5 and Figure 6. There are four dials and check boxes for independent or joint radial distortion and spatial offset compensation in horizontal and vertical directions to achieve optimally straightened images.

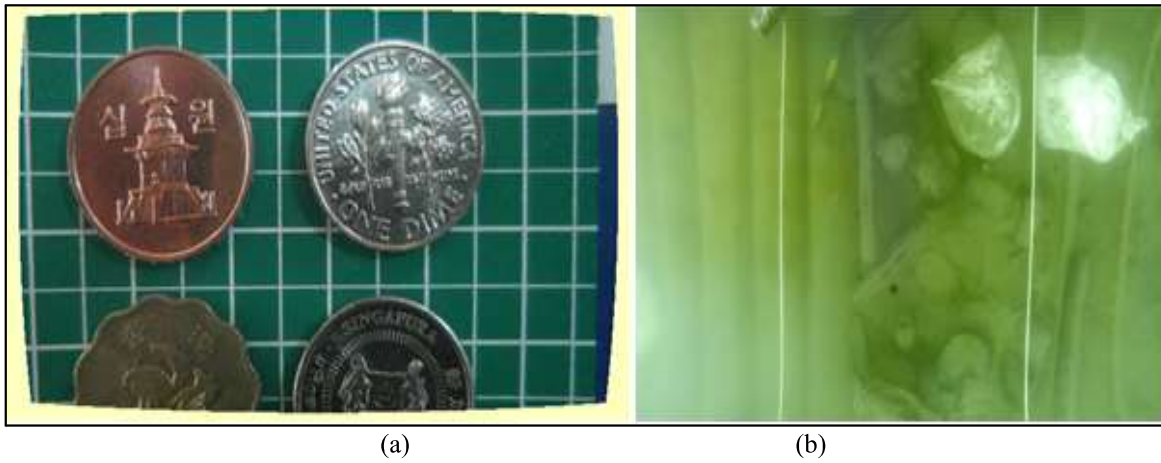


Figure 4: Photographs after radial distortion and optical axis mis-alignment correction. (a) pin-cushion distortion taken using a regular lens with a flat view port and (b) barrel distortion taken using a fisheye lens with a dome port.



Figure 5: Screenshot image of PicMan after distortion correction.

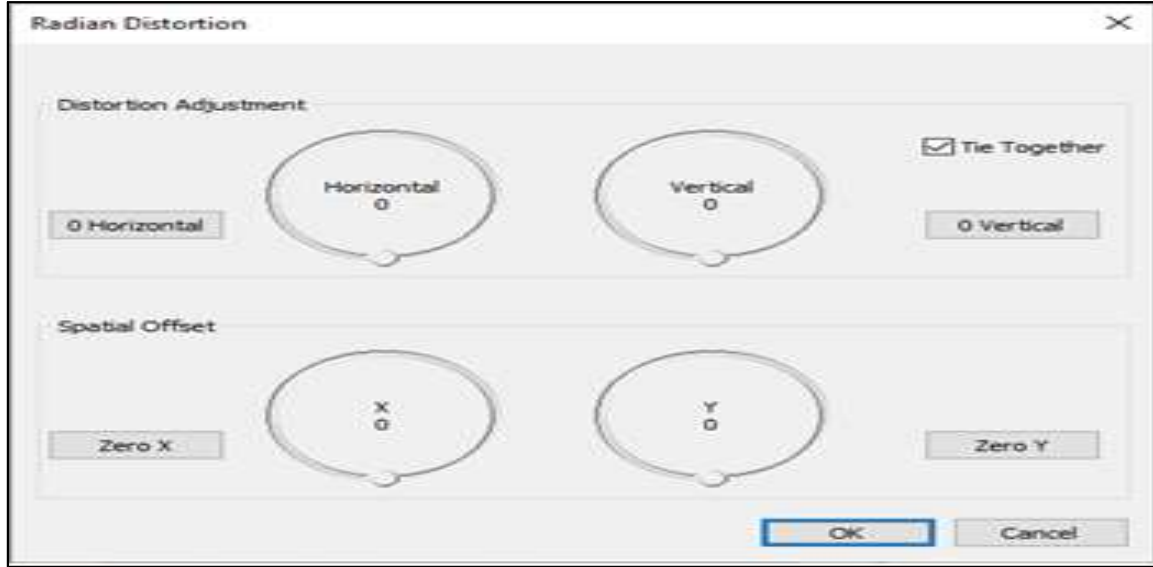


Figure 6: Screenshot of image distortion correction popup window of Image Processing/Analysis Software (PicMan, WaferMasters, Inc.) used in this study.

SUMMARY

Modern underwater photography equipment is very expensive and sometimes will be hard to afford due to budgetary reasons. Many underwater excavation sites have to use less ideal equipment, not only from the budgetary reasons, but also from the visibility limitations. It is definitely the case for the underwater excavation, under very turbid environments near the shoreline of the Yellow Sea.

To make image distortion correction easier and precise, regardless of the photography equipment of choice, we have developed a very flexible, distortion correction (compensation) algorithm for underwater photographic images. The newly developed function is able to compensate distortions arising from optical misalignment and offset regardless of type of lenses and viewports. The new function is added to the unified image processing software (PicMan from WaferMasters, Inc.) for convenient usage at underwater archaeological sites and offices in any locations using ordinary notebook PCs.

We were able to compensate distorted underwater images more precisely using the new function. Both pincushion and barrel distortion with complexity was successfully demonstrated using the new function. The distortion correction process can be done image by image, batch to batch or as video files. Archived images with distortions can also be corrected and transformed into straightened images.

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