DEVELOPING ORTHOGRAPHIC VIEWS FROM FISHEYE PHOTOGRAPHS

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ABSTRACT:

In close-range photogrammetry, the exploitation of fisheye photographs for dimensional information has been overlooked due to an apparent lack of techniques for correcting the curvilinear perspective. This paper presents a new procedure for transforming the distorted perspective of the fisheye view into corrected standard perspective views that then may be rectified into orthographic views by standard graphical techniques. Corrections resulting in standard one-, two-, and three-point perspective are described. Computer-aided design was used in addition to graphical and mathematical checks to ensure the accuracy of the work--presented here as a proof-of-concept only. The routines needed for analytical photogrammetric analysis of fisheye photographs have yet to be compiled.

KEY WORDS: Close-range photogrammetry, fisheye images, corrective procedures.

INTRODUCTION

A fisheye lens (8 mm focal length) on a standard commercial, or non-metric, 35 mm camera body yields a circular image with a field of view that extends 180 degrees (Fig. 1). This paper contains a description of a new technique to transform the circular or spherical perspective of prismatic objects in such a photograph into standard perspective views. These corrected views may then be rectified into standard orthographic presentations of the top, bottom, or sides of the prismatic object in question.

Conventional wisdom has held these circular images to be unworkable by either graphical methods (because the lines were curved, not straight) or analytical techniques (because the circular view did not conform to the colinearity concept). Although a fisheye lens is quite a bit more expensive than "normal" camera lenses, its ability to record more visual information in one view, or very few views, ought to allow it to produce more work at the same accuracy as the other lenses.

UNDERSTANDING THE FISHEYE VIEW

Experimental photographs using an Olympus 8 mm fisheye lens have shown that straight lines within the original field of view are distorted in one of three ways. When the film plane is parallel to the straight lines, the photograph produces arcs that extend to vanishing points along the perimeter of the circular image. When the film plane is perpendicular to straight lines within the field of view, the photograph produces straight lines that converge toward one vanishing point at the center of the circular image. When the film plane is at any angle other than 0 or 90 degrees to the straight lines in the field of view, the photograph yields complex curves (also referred to as transcendental curves) that still look arc-like but are not.

Figure 1. A circular fisheye photograph displaying 180 degrees of coverage in its field of view.

The sequence of grids that corresponds to these different views is displayed in Fig. 2. The grids were developed from the hemispheric Azimuthal-Equidistant map projection (suggested to this author) and range from the so-called "equatorial" view, with its nested arcs and perimeter vanishing points, through as many as 88 intermediate or oblique grids (using only one-degree intervals) finishing at the "polar" view (Snyder, 1987; Flocon and Barre, 1987). Computer-aided design methods compared observed lines in the test photographs with predicted grid lines from the suggested map projection, and produced an almost exact fit.

CORRECTING THE FISHEYE VIEW

The correction of the curvilinear perspective in two simplified fisheye views will be described here. Each view was an "arranged" photograph, taken so that the geometry in the

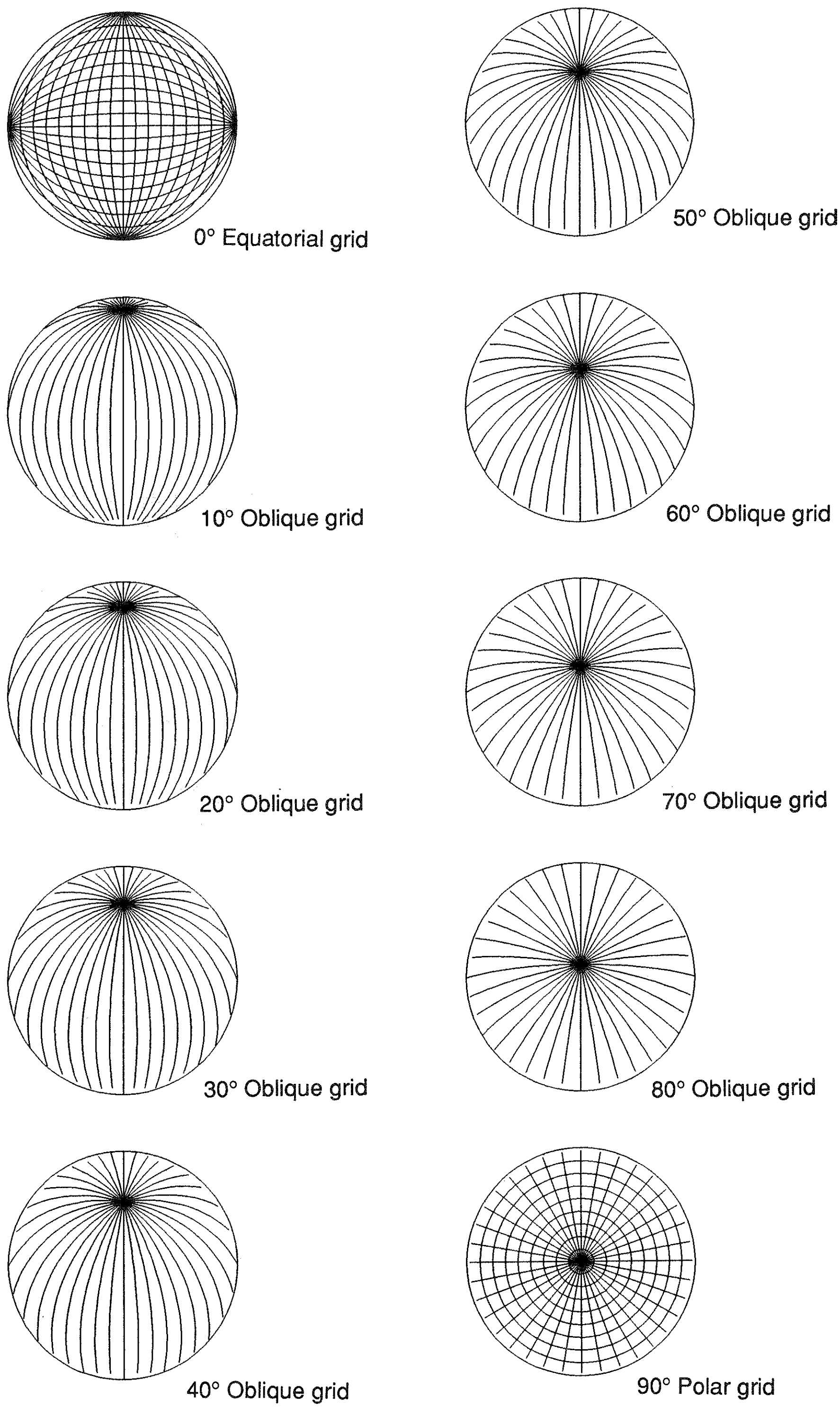


Figure 2. The sequence of grids with the geometry of the fisheye lens as generated mathematically.

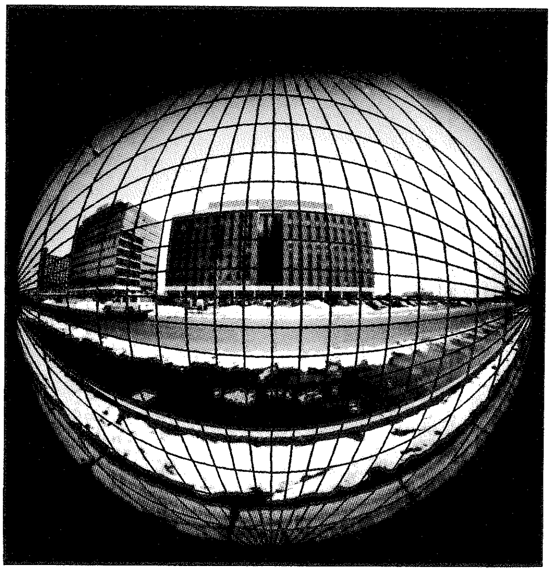


Figure 3. The distorted two-point perspective to be rectified by the first technique described in this paper.

original scene was expressed in the simplest grid patterns, the equatorial and the polar grids.

The first fisheye photograph to be corrected here was taken with the film plane parallel to the vertical straight lines that represented the corners of the building, setting up a distorted form of two-point perspective (Fig. 3). The photograph was also set up so that two of the building's sides were visible. In the resulting distorted view, the vertical edges of the building obeyed the vertical arc-shaped curves of the equatorial grid and were read as so many degrees right or left of the central meridian of the grid, and were transferred into the bottom semicircle shown in a newly devised graphical setup (Fig. 4). The upper and lower limits of each vertical edge of the building were read off the horizontal arc-shaped curves of the same grid, and were transferred to the upper semicircle shown in Fig. 4. The various angles were extended to intersect two lines drawn tangent to the midpoint of the semicircles; these two tangent lines represent the overhead and side views of a plane in the original scene. New extensions perpendicular from the plane lines serve to locate the corners of the corrected two-point perspective view. If any angles had been read below the horizon, then the projection planes would have had to have been offset by equal distances from the semicircles to allow the construction of the corrected perspective in a clear space.

Rectifying this corrected perspective view is an application of standard techniques already described in any of a variety of references (McNeil, 1954; Gracie *et. al.*, 1967; Fry, 1969; Wolf, 1974; Kelley, 1978-1983; Busby, 1981; Wiliamson and Brill, 1987; and Brill and Williamson, 1987--to name but a few). Standard mechanical and architectural drafting textbooks also describe some of these methods. The rectification of the corrected perspective yielded an orthographic view of the top of the building demonstrating a length-width ratio of 3.6:1--a match to the *in situ* measurements of the building (67.7 m x 18.6 m, or 222 feet x 61 feet).

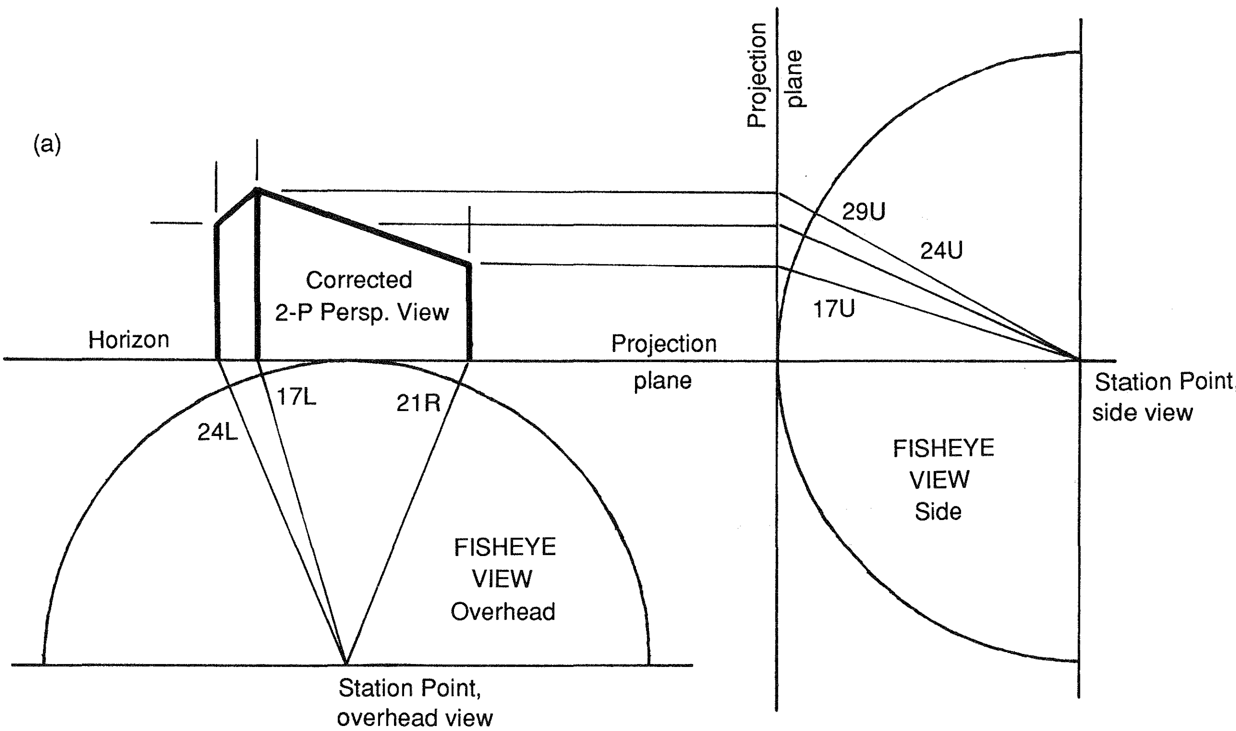
The second fisheye photograph to be corrected here was taken with the film plane parallel to one full side of the test building, setting up a distorted form of one-point perspective (Fig. 5). In this distorted view, both the vertical and horizontal edges of the building followed the arc-shaped curves of the same equatorial grid used in the previous example. Because both sets of lines were interpretable off the same grid, the corrected one-point perspective involves the same readings and plotting of angles as before, but there are fewer steps to get to the correction (Fig. 6). In this particular instance, the corrected one-point perspective happens to be same view as an orthographic drawing of that side of building.

OTHER WAYS TO DO THE SAME CORRECTIONS

Using the arranged photographs in the two examples just described is a convenient and simple proof-of-concept for the possibility of correcting curvilinear perspective. In reality, the building could have been imaged at any angle so long as the building remained within the 180-degree field of view of the fisheye lens. In such an instance, the proper oblique grid for each set of lines of the distorted building could have been used to produce a corrected three-point perspective drawing. Figure 7 shows the agreement of one oblique grid to the curved lines of the same image previously used as Fig. 3. Using this oblique grid, in conjunction with the equatorial grid used earlier, could have allowed the double-correction of the building using only one photograph.

USES FOR FISHEYE PHOTOGRAPHS

This author's personal viewpoint is that fisheye photography represents an under-exploited resource that could be tasked to do more work with fewer images than are required by conventional photography. There seems to be no reason why fisheye photographs could not provide more coverage of crime and accident scenes with fewer images, and produce maps or other drawings of the same accuracy as a greater number of conventional photographs. The polar grids could be used to exploit fisheye views taken in either zenith or nadir positions to yield maps in close quarters. Any of the oblique grids might also be applied to mapping within cramped spaces. It is only conjectural, but the curvilinear perspective of the fisheye view might be directly related to the curved-line imagery of slightly longer focal-length wide-angle lenses as well as the apparent straight-line imagery of really long focal-length lenses. However, any such reality for



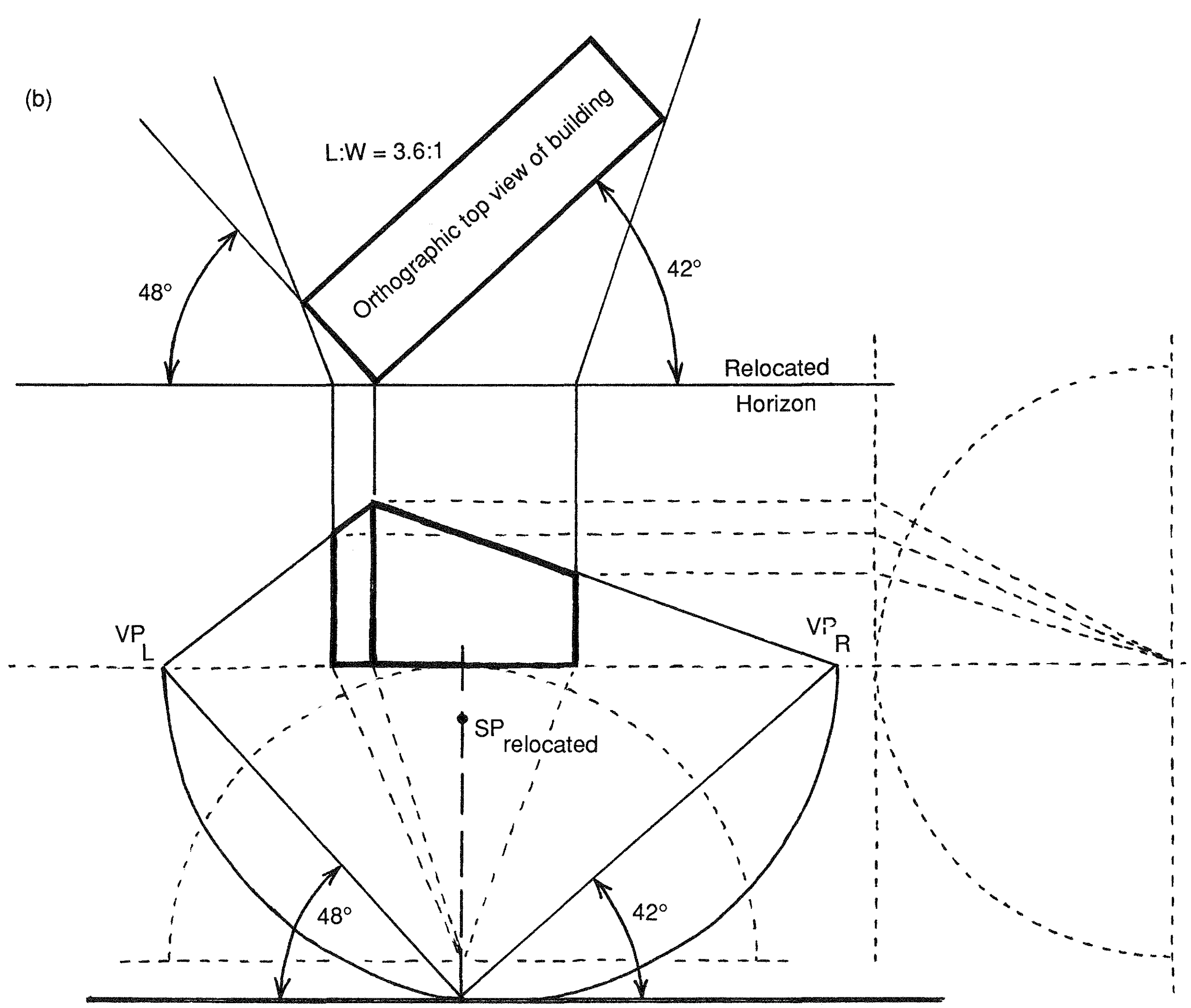


Figure 4. Correcting the fisheye view to the orthographic: (a) developing the corrected perspective, and (b) developing the orthographic presentation.

Figure 5. The distorted one-point perspective to be rectified by the second technique described in this paper.

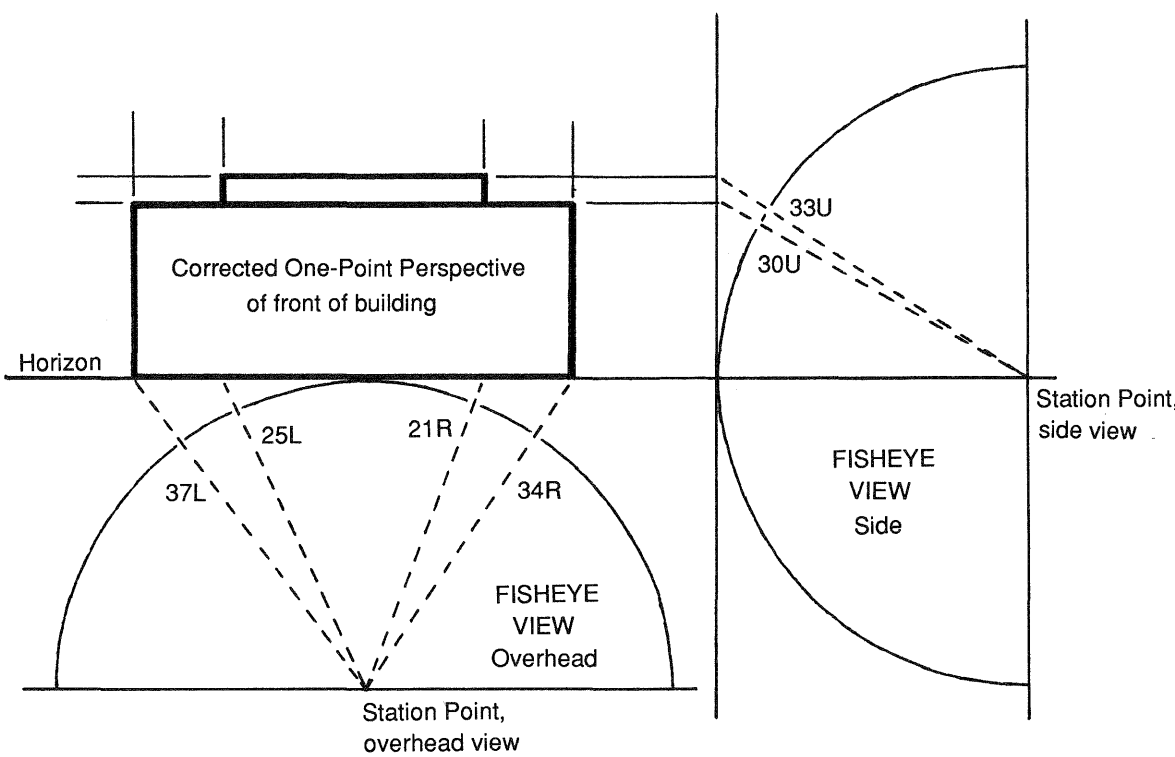


Figure 6. Correcting the fisheye view to the orthographic, developing a corrected one-point perspective.

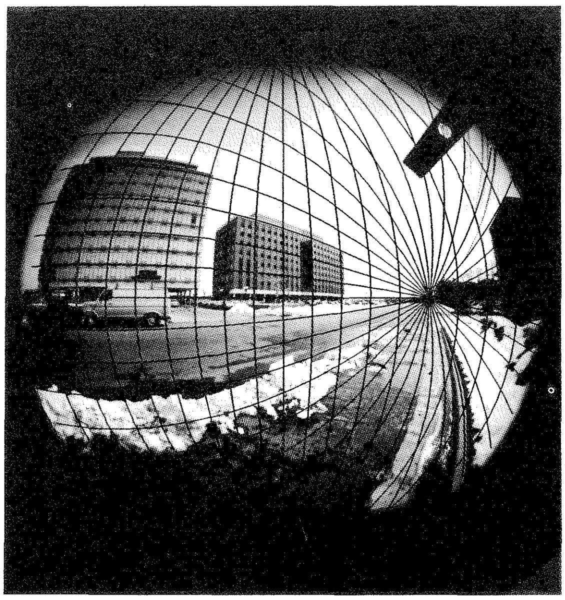


Figure 7. The distorted two-point perspective with an oblique grid overlaid atop it.

that idea is at the mercy of the design parameters for any "family" of lenses from any one manufacturer. The graphical steps for fisheye corrections demonstrated in this paper could be bypassed altogether by computerizing a mathematical model to allow analytical photogrammetry just as is done with "conventional" images at present--the only thing lacking is a compilation of the necessary mathematical routines. Just as the prototypes of ten years ago are the technological realities and mainstays of today, perhaps fisheye imaging can expand into a wide range of new roles.

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