Single Point Diamond Turning of Aluminum Mirrors for Omni Vision

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Abstract. This paper describes the manufacturing process of aluminum alloy metal mirrors used for an Ominivision system. The mirrors have hyperbolic and bi-hyperbolic. The reason for the bi-hyperbolic is that they can be used for 2 distances. The cutting condition selection is described based upon the study of the effect of feed rate on the surface finish generation. The description of the manufacturing process and the results of the machined part application are also shown.

1. Introduction

A panoramic imaging device (or *imager*) is defined by its ability to view a large portion of the scene around it, that is, to have a very large field of view (FOV) [1]. Multiple cameras and catadioptric systems are the most popular current devices; but any catadioptric or multiple camera system is subject to strict constraints on its optical design [1]. Derrien and Konolige [1] gives an overview of catadioptric devices that conform to the single viewpoint (SVP): the mirrors are rotations of conic sections. Two practical devices are a paraboloid imaged by an orthographic camera, and a hyperboloid imaged by a standard perspective camera (Figure 1 (a) and (b)). In contrast, a spheroid imaged by a perspective or orthographic camera does not have a single viewpoint (Figure 1(c)).

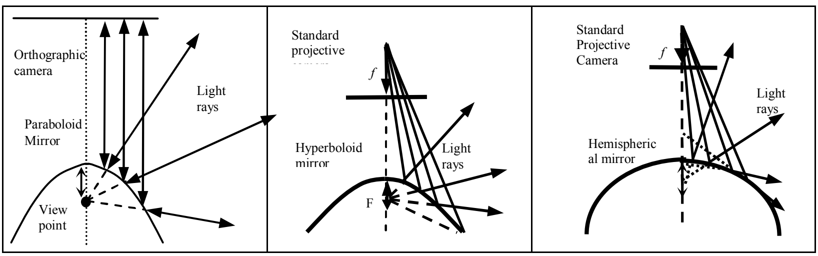


Figure 1: Paraboloid, hyperboloid, and spheroid mirror systems. The spheroid does not have a single viewpoint [1].

2. Hyperbolic Mirror Manufacturing

A hyperbolic mirror can be defined, as presented in Svoboda et al. (1997), in a coordinate frame centered in the mirror focal point *F'*, as shown in Fig. 3, by the following equation, function of the mirror parameters *a* and *b*

$$y = \sqrt{a^2 \cdot \left(1 + \frac{x^2}{b^2}\right)} - \sqrt{a^2 + b^2} \quad (1)$$

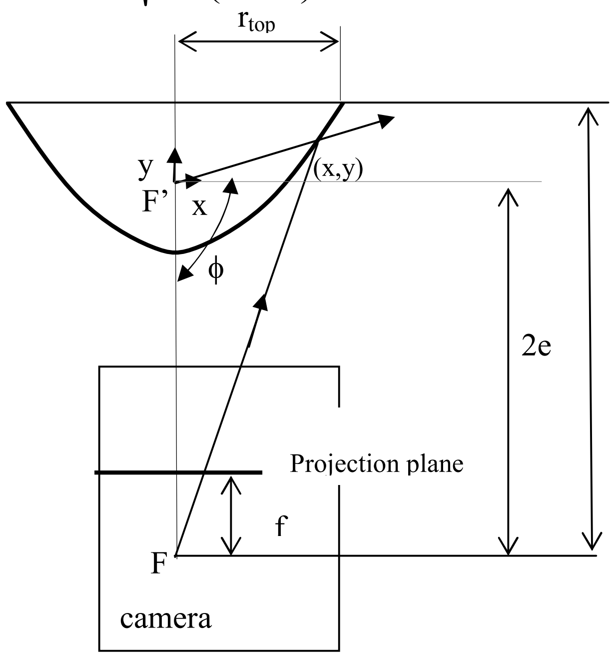


Figure 2: Hyperbolic mirror and camera geometry.

According to the specification of the camera and lens used in the vision system, we considered the following approximate parameters : f = 12 *mm* the measure in millimeters of the size of each pixel in the camera CCD (*tpixel*) *tpixel* = 0.01 *mm*. The image acquired by the camera is 640 x 480 pixels. We want that the mirror rim in the image have a radial dimension of *rpixel* = 240 pixels. The full description of the mirrors specifications is found elsewhere [3]. The hyperbolic mirror used in this project was manufactured using aluminum in two steps: (1) using a conventional lathe machine we give the aluminum piece a shape close to the desired shape of the mirror and (2) using the ultra-precision CNC lathe we achieved the final shape and finishing of the surface with mirror quality. After this, the surface was already reflexive and could be directly used in the vision system. To avoid scratches on the surface, a thin coating of rock crystal could be applied to the surface. This coating was not applied to the manufactured mirror, so an acrylic cylinder was used in the omnidirectional vision system to confine the mirror and keep it safe from scratches. In order to machine the mirror surface using the ultra-precision lathe, we had to properly choose the points to be programmed on the lathe. A method described by Palma [4] to compute the coordinates of the points to be programmed into the lathe that would keep the shape error within a desired limit was used. The tool radius compensations when computing the position of the points was done as well. The tool radius when computing the position of the points was compensated as well. Figure 3 (a) shows the manufactured (a) hyperbolic mirror and; (b) bi-hyperbolic made of aluminum with 40 *mm* of diameter.

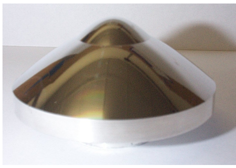

a)

b)

Figure 3: Diamond turned mirrors for Omnivision System (a) hyperbolic mirror (ϕ 40 *mm)* and; (b) bi-hyperbolic (ϕ 20mm and ϕ 60 *mm)* made of aluminum.

Figure 4 (a) and (b) shows the mobile robot with the omnidirectional vision system using the hyperbolic mirror, respectively. Some tests with the hyperbolic and with the spherical mirror were made (at *Lab. Percepção Avançada (LPA) Depart. Eng. Mecatrônica e Sistemas Mecânicos EP- USP*). The image unwarping methods were implemented and applied to images acquired by the vision system. Figure 4 (c) shows an image acquired by the omnidirectinal vision system using the hyperbolic mirror. Figure 4 (d) shows the acquired image unwrapped by the method that uses the mirror equation to map pixels in a radial line of the omnidirectional image to a vertical line in the panoramic image [3].

In summary, hyperbolic mirrors were manufactured by diamond turning aluminum in an ultraprecision CNC lathe. Some examples of the acquired images by the omnidirectional vision system and some results from the different image unwarping methods implemented.

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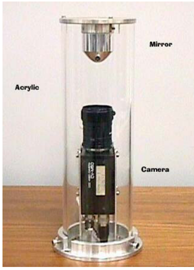
a)


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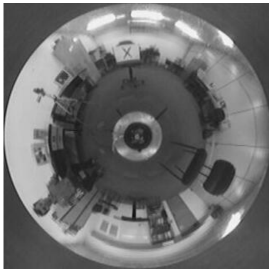
c)


d)

Figure 4. (a) Mobile robot with omnidirectional vision system; (b) Omnidirectional vision system prototype with hyperbolic mirror; (c) Example of a panoramic image obtained by the omnidireccional vision system and; d) an example of a recovered panoramic view from the device [3].

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