등거리 투사방식의 절첩형 반사굴절 전방위 렌즈

Folded catadioptric panoramic lens with an equi-distance projection

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Catadioptric panoramic lenses are widely used in various disciplines such as security/surveillance, mobile robots/vehicles, teleconferencing, and panoramic photography. Popular panoramic mirror shapes include sphere, cone, parabola and hyperbola. However, the projection scheme (i.e. incident ray direction versus reflected ray direction) for such traditional mirrors is not ideal and image resolutions vary for different incident ray directions. On this reason, we have derived a general formula for a panoramic mirror with an unspecified projection scheme. Referring to the schematic diagram shown in Fig. 1, a general non-single-viewpoint panoramic mirror profile in spherical coordinate is given as $r(\theta) = r(\theta_1)\exp\left[\int_{\theta_1}^{\theta} \frac{\sin\theta' + \cot\phi\cos\theta'}{\cos\theta' - \cot\phi\sin\theta'} d\theta'\right]$, where θ_1 is the lower bound for the integral and ϕ is the zenith angle of the tangent plane at the reflection point of the mirror. Ranges of the incident and reflected rays are given as δ_1, δ_2 and θ_1, θ_2.

For an optical instrument which has a planar image sensor such as a film or CCD sensor, the best projection scheme is the equi-distance projection scheme where the pixel distance from the center of the image sensor is directly proportional to the incident ray directions. In the equi-distance projection scheme, the zenith angle ϕ for the tangent plane is fixed by a relation given as $\tan\theta = \beta\delta + \psi$ with the two coefficients given as $\beta = \frac{\tan\theta_2 - \tan\theta_1}{\delta_2 - \delta_1}$ and $\psi = \frac{\delta_2\tan\theta_1 - \delta_1\tan\theta_2}{\delta_2 - \delta_1}$. Fig. 2 shows a designed mirror profile where ρ_1 = 5.0cm and θ_1, θ_2, δ_1 and δ_2 are given respectively as 10°, 20°, 45° and 180°. Fig. 3 shows the zenith angles for the incident and reflected rays versus the corresponding pixel position in the image sensor. As can be seen from the graph, this mirror implements a perfect equi-distance projection scheme.

In some occasions, it can be inconvenient if the imaged area is mostly in the rear directions of the camera as is the case depicted in Fig. 1. In that case, the optical path can be folded using a second mirror. Fig. 4 shows the position and the size of the two mirrors comprising a folded panoramic lens with an equi-distance projection scheme. The height of the ring-shaped planar mirror is given as $z_0 = \rho_1 \cot\theta_2$ and the new coordinate of the aspheric mirror is given as $Z(\rho) = 2z_0 - z(\rho)$.

In conclusion, we have derived a new equation describing a panoramic mirror profile with an equi-distance projection scheme [1]. The experimental results will be presented during the session.

[1] G. Kweon, "Panoramic lens and optical system using the same", *patent pending in application.*

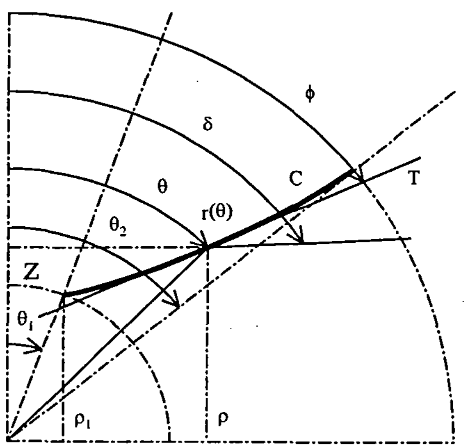

Fig. 1: Schematic diagram illustrating specular reflections in the panoramic mirror.

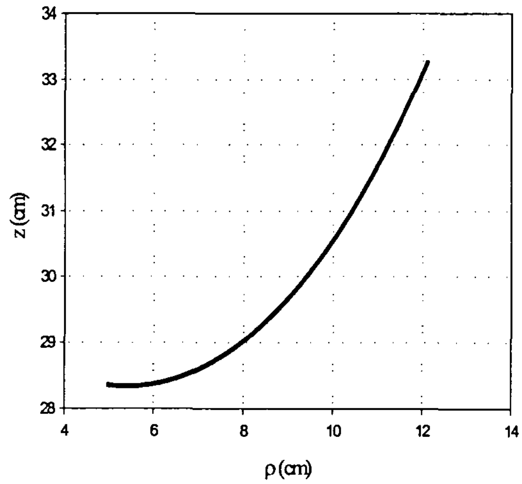

Fig. 2: Designed mirror profile with an equi-distance projection scheme.

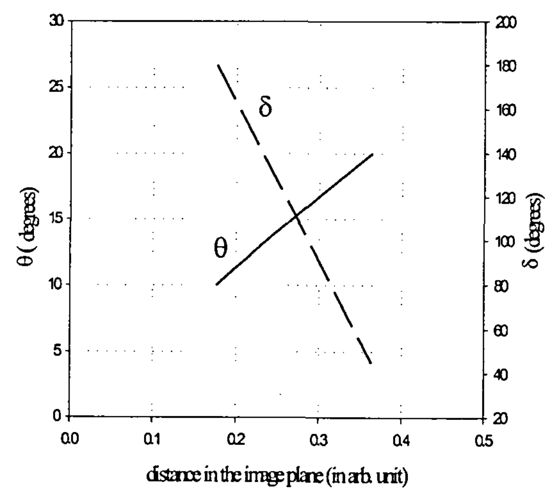

Fig. 3: The zenith angles for the incident and reflected rays versus the corresponding pixel position.

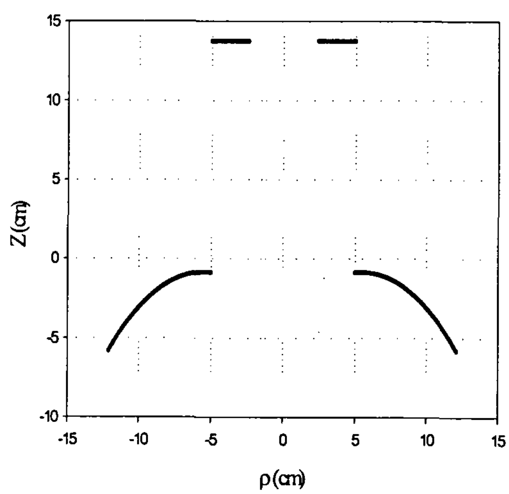

Fig. 4: The folded mirror construction.