Transformation of panoramic view

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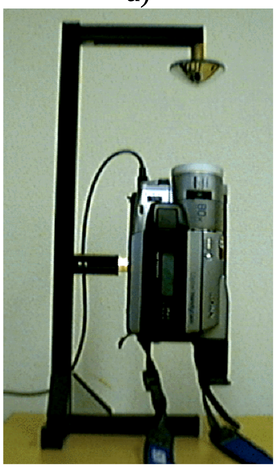
1 Introduction

The aim of this paper is description of transformation view from hyperbolic mirror to panoramic view. The system is based on standard camera equipped with non-planar mirror. It's used digital camera Sony DCR-TRV310E and hyperbolic class mirror H3G with mirror holder from Neovision. The purpose is to develop system for human tracking and gesture recognition. Figure 1 shows our panoramic vision system which consist of presented digital camera with hyperbolic mirror used to capture panoramic images.

a)



b)

Figure 1 : a) Set-up with conventional camera and mirror holder b) An image from hyperbolic mirror

This mirror isn't designed to have a unit angular gain and thus the pixels cover varying spatial angles. The circle with the highest number of pixels is the border of mirror. Small circle in the center is mapped to a single pixel. This is the cause of non-uniform distribution of vertical resolution. The image formation can be expressed as a composition of coordinate transformations and projections.

1.1 Hyperboloid mirror

The matching of a hyperboloid mirror is difficult, but it has a single center of projection. A picture taken with this mirror can be transformed to normal perspective images, cylindrical images and is best for systems using normal cameras.

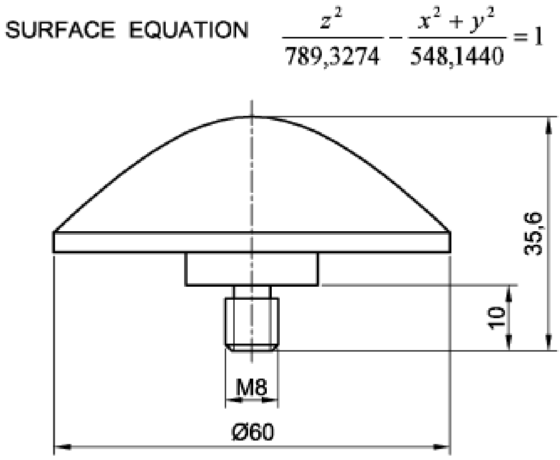


Figure 2 : Hyperbolic mirror parameters

2 Imaging model

This model describes the relationship between the coordinates of a 3D world point X and its corresponding point Y in the camera. The equation of hyperboloid system is

$$\frac{(z+e)^2}{a^2} - \frac{x^2+y^2}{b^2} = 1 \tag{2.1}$$

where a,b are mirror parameters and $e = \sqrt{a^2+b^2}$ stands for eccentricity.

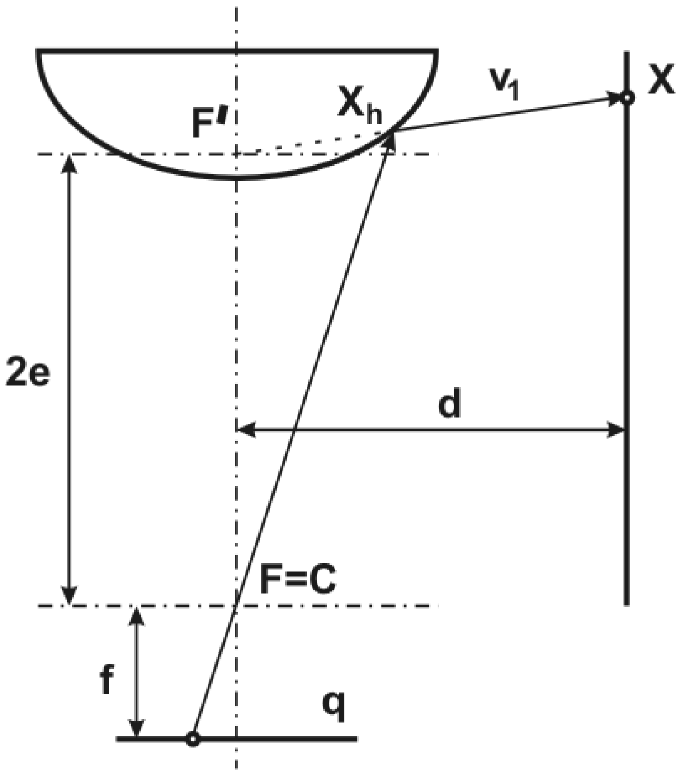


Figure 3 : Imaging model of Central Panoramic Camera with hyperbolic mirror

The transformation between the world system and the mirror system is expressed by rotation matrix R_M and translation vector t_M . The second transformation, between the mirror system and the camera coordinate system is marked by R_C and t_C . The camera center has to coincide

with the second focal point of the mirror. The translation thus must be $t_C = [0,0,-2e]^T$ .It is convenient to set $R_C = I_3$ to simplify computations.
Let a 3D point X be expressed in some world coordinates. The point X is translated by t_M and rotated by R_M into the mirror coordinate system

$$X_M = R_M(X - t_M) \tag{2.2}$$

The point X_M is projected by a central projection on the surface of the mirror. Let the point on the mirror be denoted by X_h. The line v_1 going from F' to X_M consists of points

$$v_1 = \{F' + \lambda X_M = \lambda[x_M, y_M, z_M]^T, \lambda \in R\} \tag{2.3}$$

We insert the line eq. 2.3 into the mirror equation 2.1 and compute solution for λ

$$\lambda_{1,2} = \frac{b^2\left(-ez_M \pm a\|v\|\right)}{b^2 z_M^2 - a^2 x_M^2 - a^2 y_M^2} \tag{2.4}$$

After the correct λ is computed, the expression for mirror point reads as

$$X_h = \lambda X_M \tag{2.5}$$

Point X_h is translated the vector $t_C = [0,0,-2e]^T$ and rotated by R_C into the coordinate system of the camera and projected into the vector u representing the normalized image coordinates

$$u = \frac{1}{z_C} R_C(X_h - t_C), \text{ where } z_C = R_{C3}^T(X_h - t_C) \tag{2.6}$$

The vector u is transformed into homogenous pixel coordinates using camera calibration matrix K. Complete model can be concisely rewritten as

$$q = K\frac{1}{z_C} R_C(\lambda R_M(X - t_M) - t_C) \tag{2.7}$$

2.1 Transformation

The coordinates of panoramic view are P_x and P_y. We must transform these coordinates to mirror system. The world points X are projected on cylinder whose radius is equal d. Axis of cylinder is coincident with the mirror and camera axis it comes to this, that cylinder axis is equal z axis. We can compute horizontal size of panoramic view as perimeter of cylinder $Width = 2\pi d$.

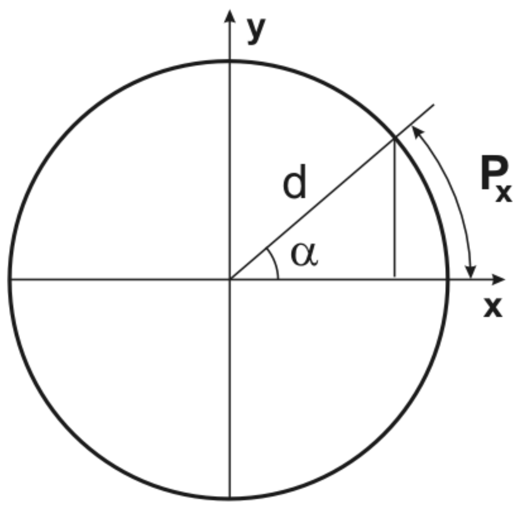


Figure 4 : Transformation coordinates of panoramic view

The coordinates of mirror point X_M are following $x_M = d * \cos\alpha, y_M = d * \sin\alpha, z_M = P_y$, where angle $\alpha = \frac{P_x}{d}$. Projected ray doesn't intersect pixel in input view distinct. We can compute weighted average of neighbor pixels. These method prevents aliasing.

3 Conclusion

This paper gives directions how transform view from omnidirectional system to panoramic view. Equations from imaging model are used for our transformation. The output of this system will be used to human tracking and gesture recognition. Advantage this system is covering whole area of 360 degrees, but varying resolution on the other hand.

4 References

[1] Svoboda, T., Central Panoramic Cameras Design, Geometry, Egomotion, Center for Machine Perception, Faculty of Electrical Engineering, Czech Technical University, September 30, 1999.

[2] Nayar, S., Baker, S., A Theory of Catadioptric Image Formation, Department of Computer Science, Columbia university, Technical Report CUCS-015-97.