Line extraction in uncalibrated central images with revolution symmetry

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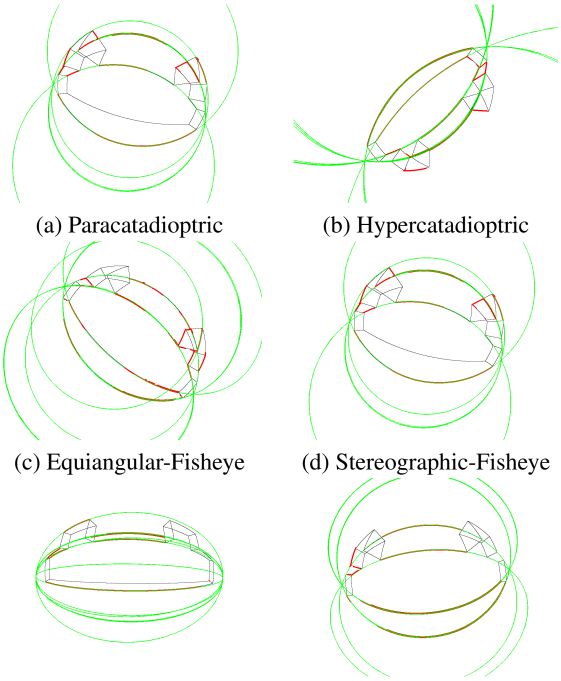

(a) Paracatadioptric (b) Hypercatadioptric (c) Equiangular-Fisheye (d) Stereographic-Fisheye (e) Orthogonal-Fisheye (f) Equisolid-Fisheye

Figure 1: Extraction example on simulated images.

In omnidirectional cameras, straight lines are projected onto curves called line-images. The shape of these curves is strongly dependent of the particular camera configuration. The great diversity of omnidirectional camera systems makes harder the line-image extraction in a general way. Therefore, it is difficult to design uncalibrated general approaches, and existing methods to extract lines in omnidirectional images require the camera calibration. In this paper, we present a novel method to extract line-images in uncalibrated images which is valid for radially symmetric central systems.

In central systems the projection surface of a 3D line is a plane which has two degrees of freedom (DOF). That means we only can recover two of the four degrees of freedom of the line from a single projection. If a line-image is a curve which has more than two degrees of freedom, the extra DOFs implicitly encodes the projection model and the line-image can be used to compute the calibration [2, 3].

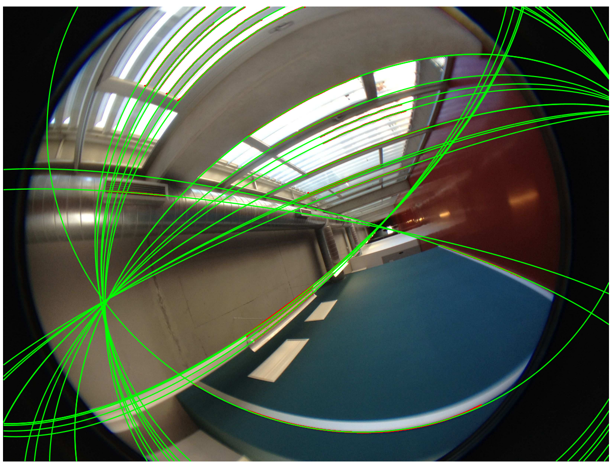

Figure 2: Extraction example on real equiangular-fisheye image

Perspective	$(l_1+l_2+l_3)=0$
Para catadioptric	$\hat{r}_{vl}=\sqrt{\frac{l_1\hat{r}_1^2+l_2\hat{r}_2^2+l_3\hat{r}_3^2}{l_1+l_2+l_3)}}$
Hyper catadioptric	$\hat{r}_{vl}=\sqrt{\left(\frac{l_1\sqrt{\hat{r}_1^2+f^2}+l_2\sqrt{\hat{r}_2^2+f^2}+l_3\sqrt{\hat{r}_3^2+f^2}}{l_1+l_2+l_3}\right)^2-f^2}$
Equiangular fisheye	$l_1\hat{r}_1\cot\left(\frac{\pi}{2}\frac{\hat{r}_1}{\hat{r}_{vl}}\right)+l_2\hat{r}_2\cot\left(\frac{\pi}{2}\frac{\hat{r}_2}{\hat{r}_{vl}}\right)+l_3\hat{r}_3\cot\left(\frac{\pi}{2}\frac{\hat{r}_3}{\hat{r}_{vl}}\right)=0$
Stereographic fisheye	$\hat{r}_{vl}=\sqrt{\frac{l_1\hat{r}_1^2+l_2\hat{r}_2^2+l_3\hat{r}_3^2}{l_1+l_2+l_3}}$
Orthogonal fisheye	$l_1\sqrt{\hat{r}_{vl}^2-\hat{r}_1^2}+l_2\sqrt{\hat{r}_{vl}^2-\hat{r}_2^2}+l_3\sqrt{\hat{r}_{vl}^2-\hat{r}_3^2}=0$
Equisolid fisheye	$l_1\frac{\hat{r}_1^2-\hat{r}_{vl}^2}{\sqrt{2\hat{r}_{vl}^2-\hat{r}_1^2}}+l_2\frac{\hat{r}_2^2-\hat{r}_{vl}^2}{\sqrt{2\hat{r}_{vl}^2-\hat{r}_2^2}}+l_3\frac{\hat{r}_3^2-\hat{r}_{vl}^2}{\sqrt{2\hat{r}_{vl}^2-\hat{r}_3^2}}=0$

Table 1: Three points line-image constraint for different central projection systems with revolution symmetry.

In our proposal we exploit the line-image description

$$n_x\hat{x}\pm n_y\hat{y}-n_z\hat{\alpha}(\hat{r})=0\,, \tag{1}$$

presented in [1], to develop the unified line-image constraint which is described as

$$l_1\hat{\alpha}_1+l_2\hat{\alpha}_2+l_3\hat{\alpha}_3=0. \tag{2}$$

The unified main calibration parameter $\hat{r}_{vl}$ encodes calibration information in different types of camera systems, dioptric and catadioptric. The line-image constraint (2) is analytically solved for each camera system (Table 1) allowing us to extract simultaneously the projection plane of the line and the main calibration parameter from three points of the line-image. Using in addition gradient-based information we recover the uncalibrated line-image from a minimum of two image points,

$$-\nabla I_y n_x\pm\nabla I_x n_y+n_z\frac{\partial\hat{\alpha}}{\partial\hat{r}}\frac{1}{\hat{r}}\left(\hat{x}\nabla I_y-\hat{y}\nabla I_x\right)=0, \tag{3}$$

by linearly approximating the distortion function α around the main calibration parameter $\hat{r}_{vl}$

$$\hat{\alpha}(\hat{r})=\frac{\partial\hat{\alpha}(\hat{r}_{vl})}{\partial\hat{r}}(\hat{r}-\hat{r}_{vl})\,. \tag{4}$$

This scheme is used in a line-image extraction algorithm to obtain lines from uncalibrated omnidirectional images without any assumption about the scene.

The algorithm is evaluated with synthetic images for a collection of different catadioptric and dioptric systems (Fig. 1). It has been also tested with real images and sequences for hyper-catadrioptic and equiangular-fisheye systems (Fig. 2) showing good performance.

[1] J. Bermudez-Cameo, G. Lopez-Nicolas, and J. J. Guerrero. A unified framework for line extraction in dioptric and catadioptric cameras. In *ACCV, Daejeon, Korea*, 2012.

[2] F. Devernay and O. Faugeras. Straight lines have to be straight. *Machine Vision and Applications*, 13(1):14–24, 2001.

[3] J.P. Tardif, P. Sturm, and S. Roy. Self-calibration of a general radially symmetric distortion model. *ECCV 2006*, pages 186–199, 2006.