AUTOMATIC GENERATION OF EPIPOLAR CURVES

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Introduction

- Depth map estimation plays an important role in many applications, such as navigation, tracking, and 3D reconstruction.
- Most depth estimation methods are based on perspective cameras and use *epipolar lines* to accelerate (point) feature matching.
- This paper aims to estimate *epipolar curves* for fisheye cameras, which will be beneficial to the depth estimation because of the wider field-of-view (FOV) of a fisheye camera.

Methods

1. Procedure of The Proposed Method

The proposed procedure of automatic derivation of epipolar curves for fisheye cameras can be summarized as follows (see Fig. 1):

Step 1: Project each 3D reference point from the two camera centers to two points on the auxiliary screen (flat-panel display).

Step 2: Connect the above two projected points with a line on the screen.

Step 3: Repeat Steps 1 and 2 to establish multiple lines on the screen.

Step 4: Find the intersection of lines obtained in Step 3 and identify its image as *epipole* in each camera view.

Step 5: Identify images of lines derived in Step 3 as *epipolar curves* (*e-curves*) in each camera view.

Step 6: If necessary, additional *e-curves* can be obtained by generating more lines passing through the above intersection.

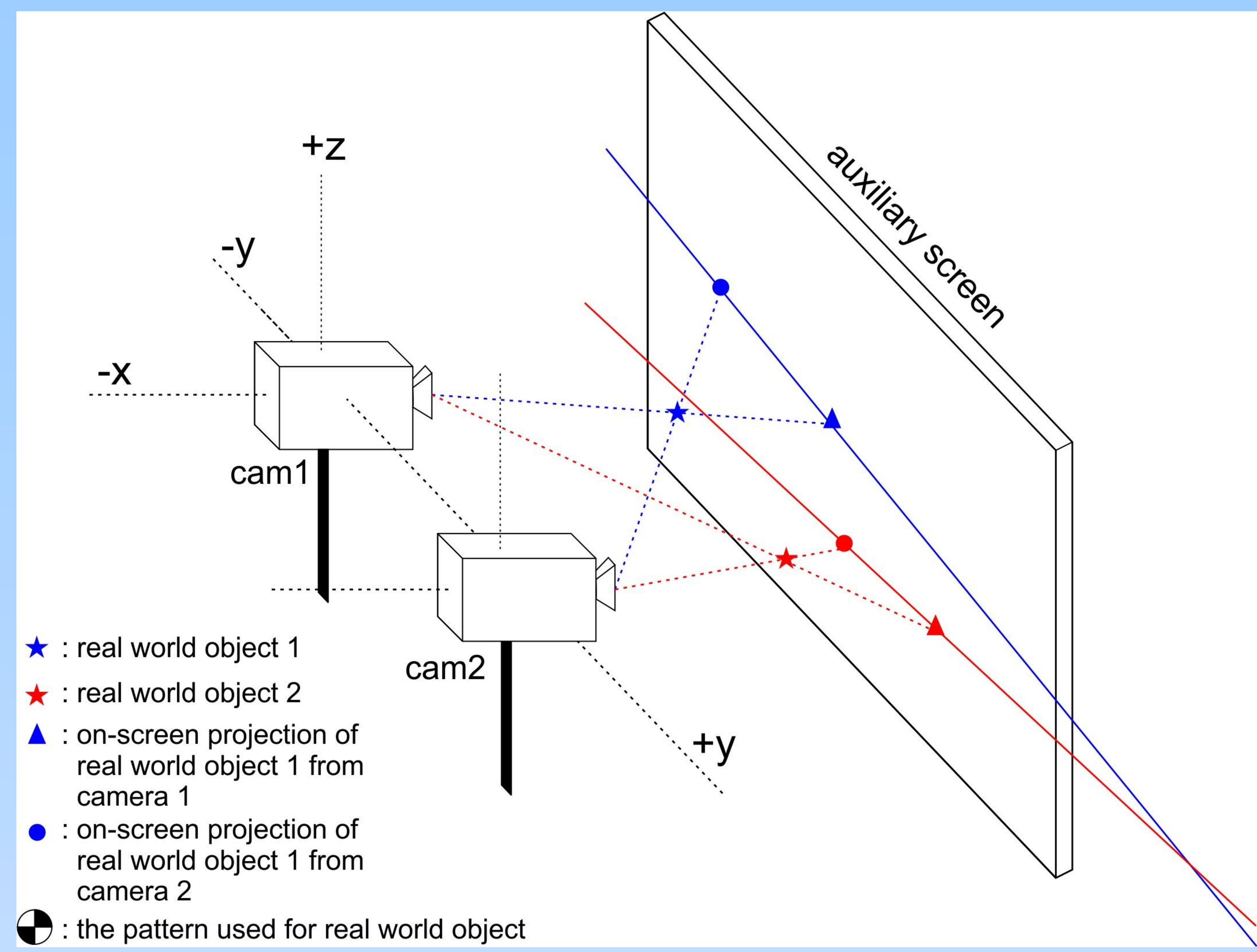

Fig. 1: System setup of the proposed method

2. Projections in Step 1

- A special circular pattern (Fig. 2 left) is used to represent a 3D reference point.
- Template matching is employed to locate its position in the fisheye image using a mask (Fig. 2 right) by minimizing

$$\sum_{x',y'\in T} \left(T(x',y') - I(x+x',y+y')\right)^2$$

Fig. 2: (left) circular patter, (right) mask

- Identified 3D reference point in the fisheye image can then be projected into the screen of the auxiliary display using binary search.

3. Estimating the Intersection

- For n lines obtained in **Step 3**, with each line represented by $a_i x + b_i y = c_i$, their intersection can be estimated by the least squares solution

$$\begin{bmatrix} x \\ y \end{bmatrix} = (A^T A)^{-1} A^T B,$$

$$\text{with } A = \begin{bmatrix} a_1 & b_1 \\ a_2 & b_2 \\ \vdots & \vdots \\ a_n & a_n \end{bmatrix}; B = \begin{bmatrix} c_1 \\ c_2 \\ \vdots \\ c_n \end{bmatrix}$$

4. Performance Evaluation

- Three different camera setups are investigated.

Table 1: Different camera setups

Camera setup	Camera height (cm)		Screen depth (cm)		Stereo baseline (cm)
	Left	Right	Left	Right	
1	44	44	47	47	24.5
2	40	44	47	47	24.5
3	44	44	47	51	24.5

- **Accuracy evaluation for epipoles:** using selected subsets of ten 3D reference points.
- **Accuracy evaluation for E-curves:** using 100 equally spaced 3D reference points w. r. t. 10 corresponding *e-curves* (see Figs. 3 and 4).
  - ✓ Mean error (in pixels) is calculated from both camera views for each camera setup.

Experimental Results

Table 2: Accuracy evaluation for epipoles

Cam. setup	No. of ref. points	Distance	Error (pixel)		Intersection found in Step 4
			Mean	Std.	
1	2 points	Close	4.36	0.70	(-17574, 641)
	2 points	Far	1.06	0.67	(-36857,354)
	4 points	Far	1.05	0.61	(-34509, 310)
	6 points	Far	1.10	0.66	(-37300, 221)
2	2 points	Close	3.25	0.72	(-16675, 3549)
	2 points	Far	1.06	0.74	(-37668, 4742)
	4 points	Far	1.16	0.68	(-34969, 4558)
	6 points	Far	1.11	0.78	(-38636, 6756)
3	2 points	Close	1.00	0.84	(-2908, 467)
	2 points	Far	0.91	0.82	(-2832, 455)
	4 points	Far	0.87	0.85	(-2850, 462)
	6 points	Far	0.98	0.87	(-2860, 472)

Table 3. Accuracy evaluation for epipolar curves

Additional Treatment	Camera setup	Error (pixel)			
		Mean (one view)		Mean (overall)	Std. (overall)
		Left	Right		
-	1	1.09	1.02	1.06	0.65
	2	1.29	1.35	1.32	0.73
	3	1.07	1.07	1.07	0.73
Curve fitting	1	1.66	1.71	1.68	0.77
	2	1.75	1.95	1.85	0.78
	3	1.78	1.78	1.78	0.75

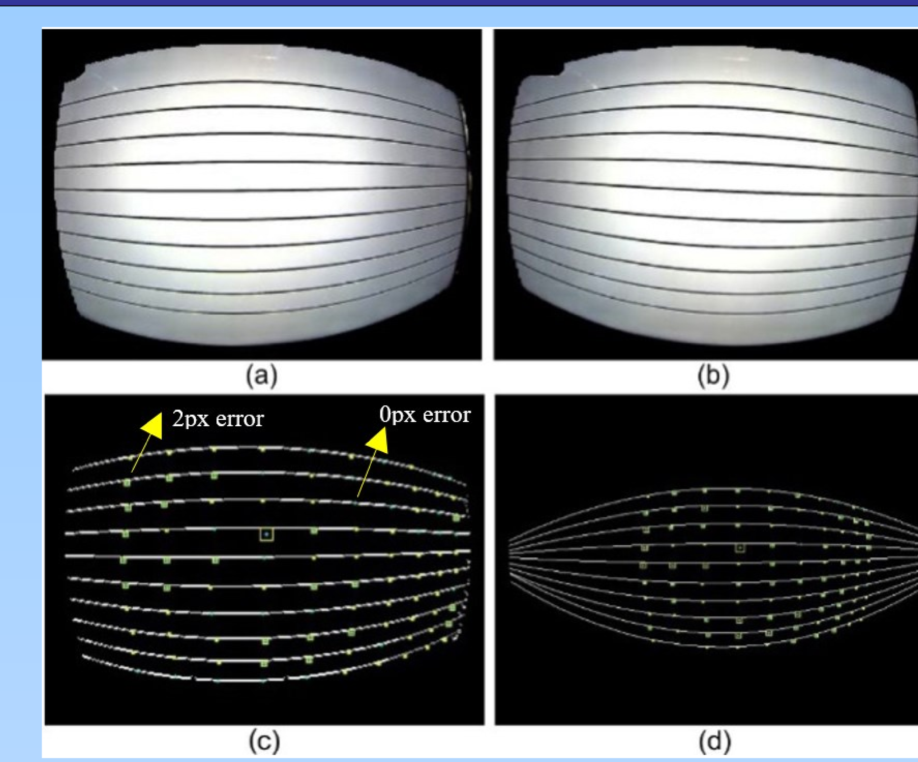

Fig 3: (a) left (b) right *e-curve* images for cam. setup 1; (c) *e-curves* extracted from (a); (d) curve fitting result of (c)

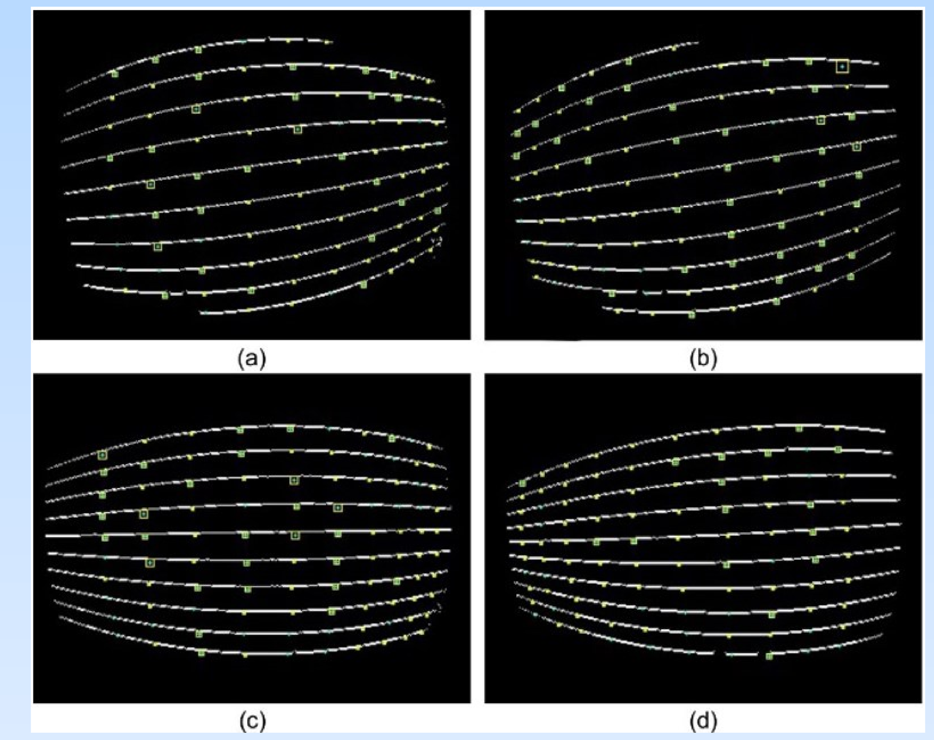

Fig. 4: left-right *e-curves* for cam. setup 2 (a-b) and 3 (c-d)

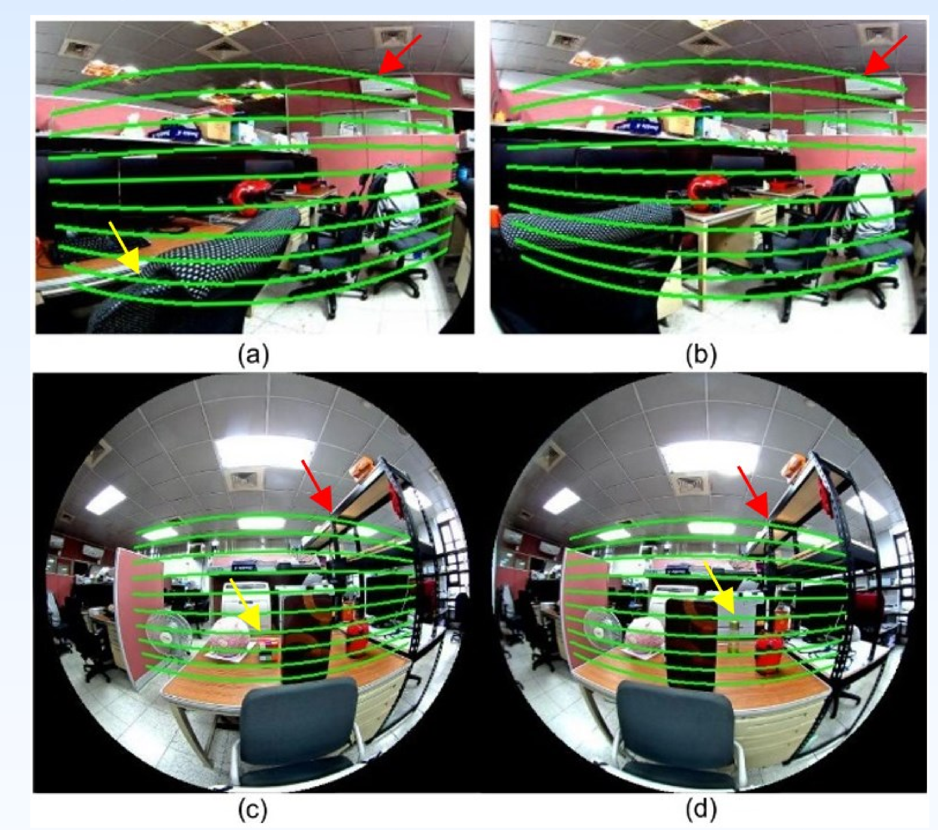

Fig. 5: Generated e-*curves* in some real world views. Red and yellow arrows show point correspondence and camera view that cannot be seen from the other camera, respectively.

Conclusion

- A novel and effective approach is proposed for automatic generation of epipolar curves, wherein reasonably accurate results can be obtained with an auxiliary flat-panel display.