SIMULTANEOUS CALIBRATION OF A STRUCTURED LIGHT-BASED CATADIOPTRIC STEREO SENSOR

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WHAT? Propose a novel calibration for the structured light-based catadioptric stereo sensor

WHY? Achieve a simpler and more robust calibration than the conventional method

HOW? Study the conventional method
Develop the novel method
Evaluate both approaches by simulation

SEQUENTIAL CALIBRATION

Stage 1: Catadioptric camera calibration using camera model (M1)

3D points $\xrightarrow[\xi,\varphi,\alpha_u,\alpha_v,u_0,v_0]{\text{Camera model (M1)}}$ Pixels } Error to be minimized
Pixels extracted in image

Stage 2: Omnidirectional laser projector calibration by surface fitting

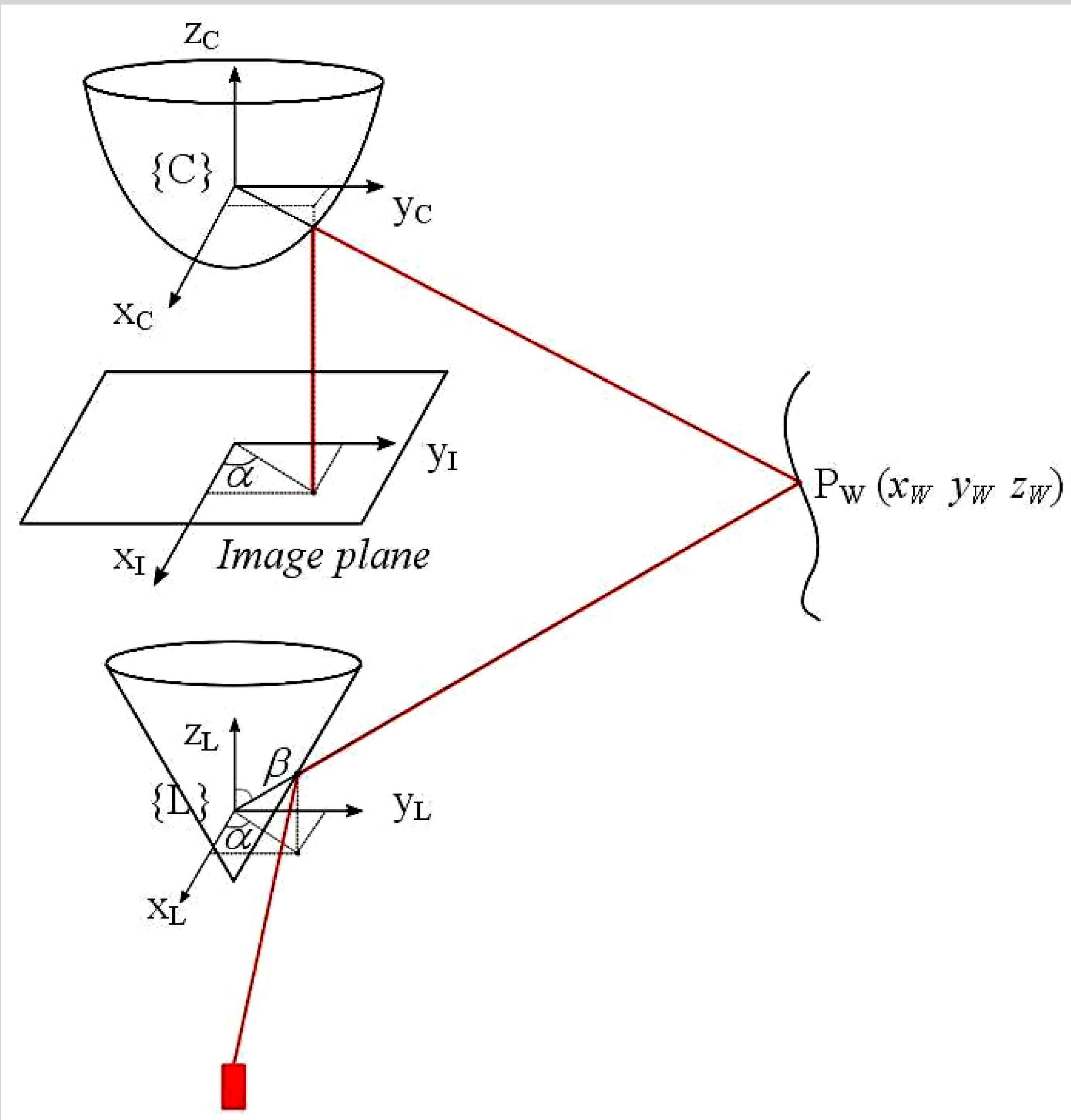
2D laser points → 3D points on sphere → 3D points on calibration planes → Fitting of quadratic surface

SIMULTANEOUS CALIBRATION

Single stage: Sensor calibration using camera model (M1) and laser projection model (M2)

3D points $\xrightarrow[\xi,\varphi,\alpha_u,\alpha_v,u_0,v_0,h,\beta]{\text{Sensor model (M1,M2)}}$ Pixels } Error to be minimized
Pixels extracted in image

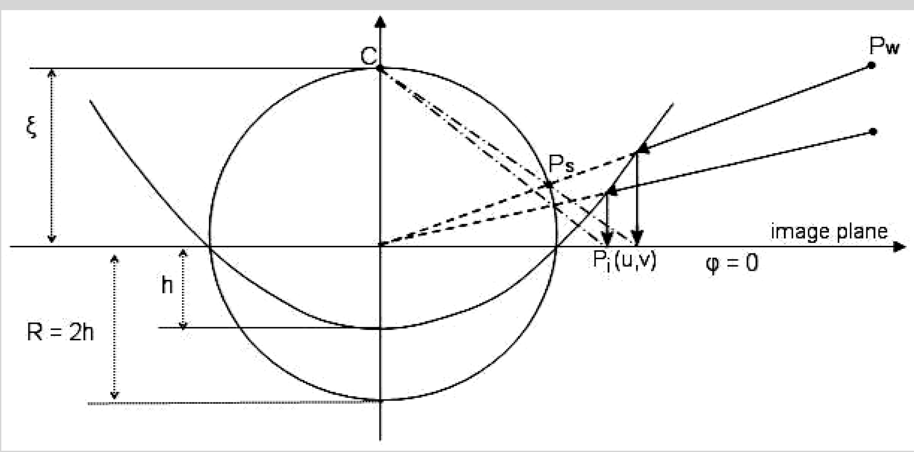
SENSOR MODELLING



Camera model (M1)

$$u = \alpha_u \frac{(\xi+\varphi)x_W}{\xi\sqrt{x_W^2+y_W^2+z_W^2}-z_W}+u_0$$

$$v = \alpha_v \frac{(\xi+\varphi)y_W}{\xi\sqrt{x_W^2+y_W^2+z_W^2}-z_W}+v_0$$



Laser projection model (M2)

$$x_W = \tan\beta(z_W+h)\left(\frac{u-u_0}{\alpha_u}\right)\Bigg/\sqrt{\left(\frac{u-u_0}{\alpha_u}\right)^2+\left(\frac{v-v_0}{\alpha_v}\right)^2}$$

$$y_W = \tan\beta(z_W+h)\left(\frac{v-v_0}{\alpha_v}\right)\Bigg/\sqrt{\left(\frac{u-u_0}{\alpha_u}\right)^2+\left(\frac{v-v_0}{\alpha_v}\right)^2}$$

3D points on calibration planes: (x_W, y_W, z_W)
2D points in image plane: (u,v)
Sensor parameters to be estimated:
- ξ : depending on the eccentricity
- φ : depending on the eccentricity and scale
- $\alpha_u,\alpha_v,u_0,v_0$: intrinsic camera parameters
- h : position of the cone of laser projection in {C}
- β : aperture angle of the cone of laser projection

COMPARISON OF TWO CALIBRATION APPROACHES

Trials with synthetic 3D and 2D points (perturbed by various Gaussian noises) and various sensor parameters to initialise the non-linear iterative algorithm

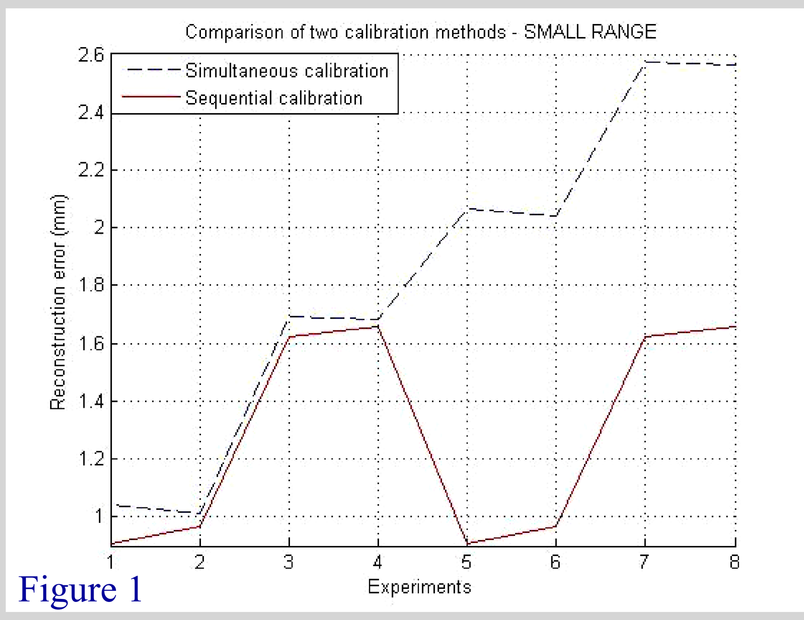


Figure 1

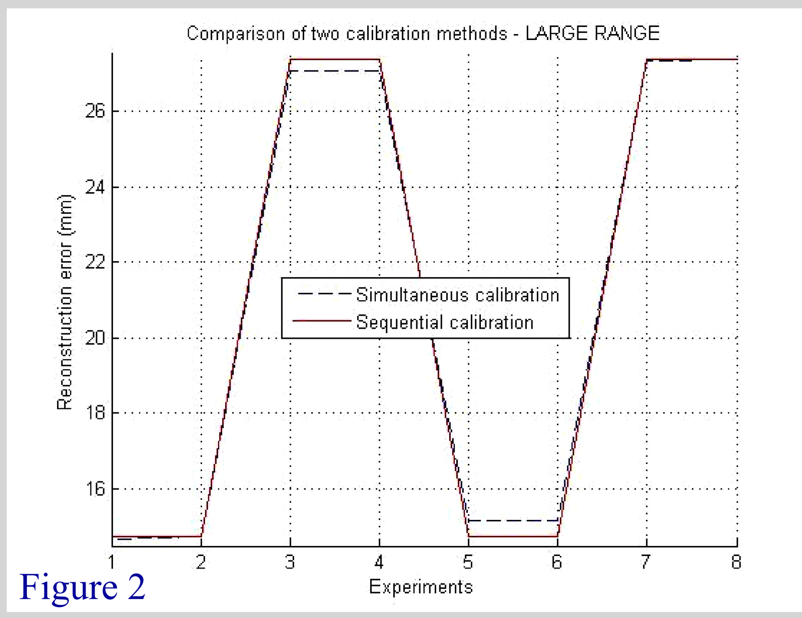


Figure 2

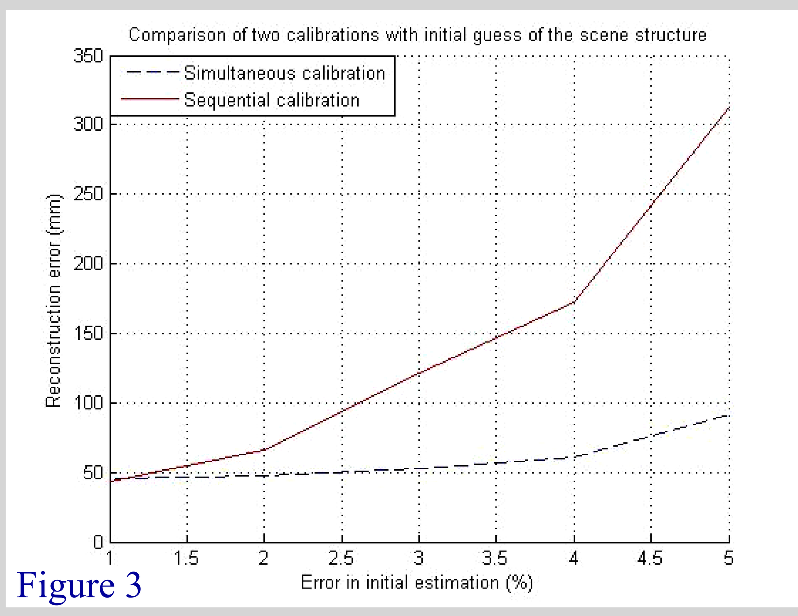


Figure 3

Fig. 1. Small range scene (1000mm):
⇨ Sequential method is better

Fig. 2. Large range scene (5000mm):
⇨ Simultaneous method is better

Fig. 3. 3D points are not measured but estimated from the scene structure:
⇨ Simultaneous is much better

	Sequential calibration	Simultaneous calibration
Accuracy	Similar accuracy in 3D reconstruction	
Sensor modelling	Similar	
Complexity	Calibration planes and known 3D points are indispensible	Scene structure can be use to estimate the 3D points
Experimentation	Successful	Future work

REFERENCES

S.K. Nayar and S. Baker. Catadioptric image formation, In *Proc. 1997 DARPA Image Understanding Workshop*, pp. 1431-1437, 1997.

R. Orghidan. Catadioptric stereo based on structured light projection. PhD thesis, Universitat de Girona, 2006.

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