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Design and calibration of a new high-definition three-dimensional laparoscopic system

Key words: Dual optical channels, Three dimensional, Camera calibration, Pinhole model, Depth measurement, Laparoscopic system

Contact: Li-qiang Wang,
E-mail: wangliqiang@zju.edu.cn
ORCID: http://orcid.org/0000-0002-9940-4480

Introduction

- One of the most important challenges surgeons have had to face is the loss of depth perception because of the 2D vision of laparoscopic.

- A 3D laparoscopic system with more accurate depth perception may improve the efficiency, shorten the learning curve, and reduce the operating time of the surgery.

- A new 3D laparoscopic system which includes a dual channel optical system, two cameras, a camera control unit, and a 3D monitor has been introduced in this article.

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The optical system of 3D laparoscope

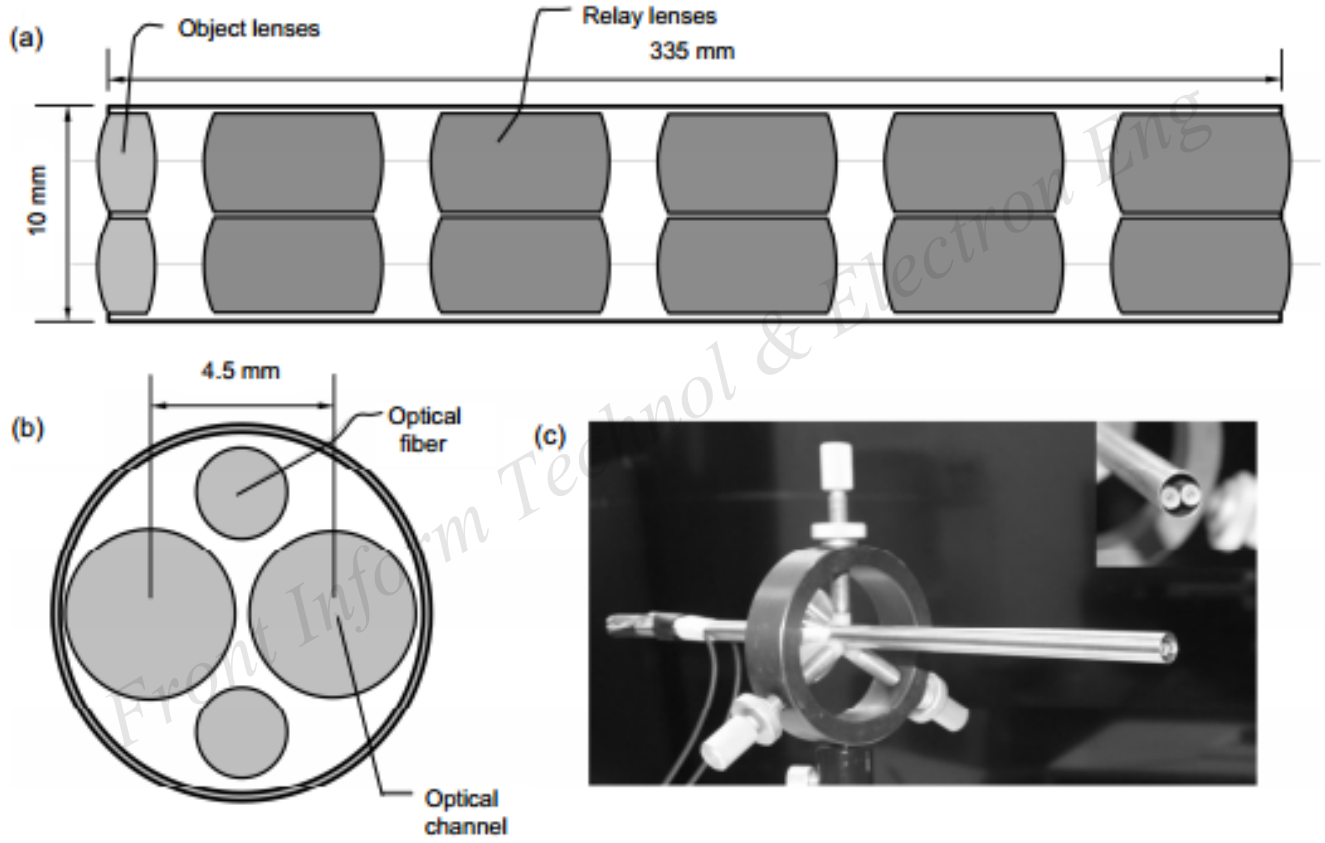
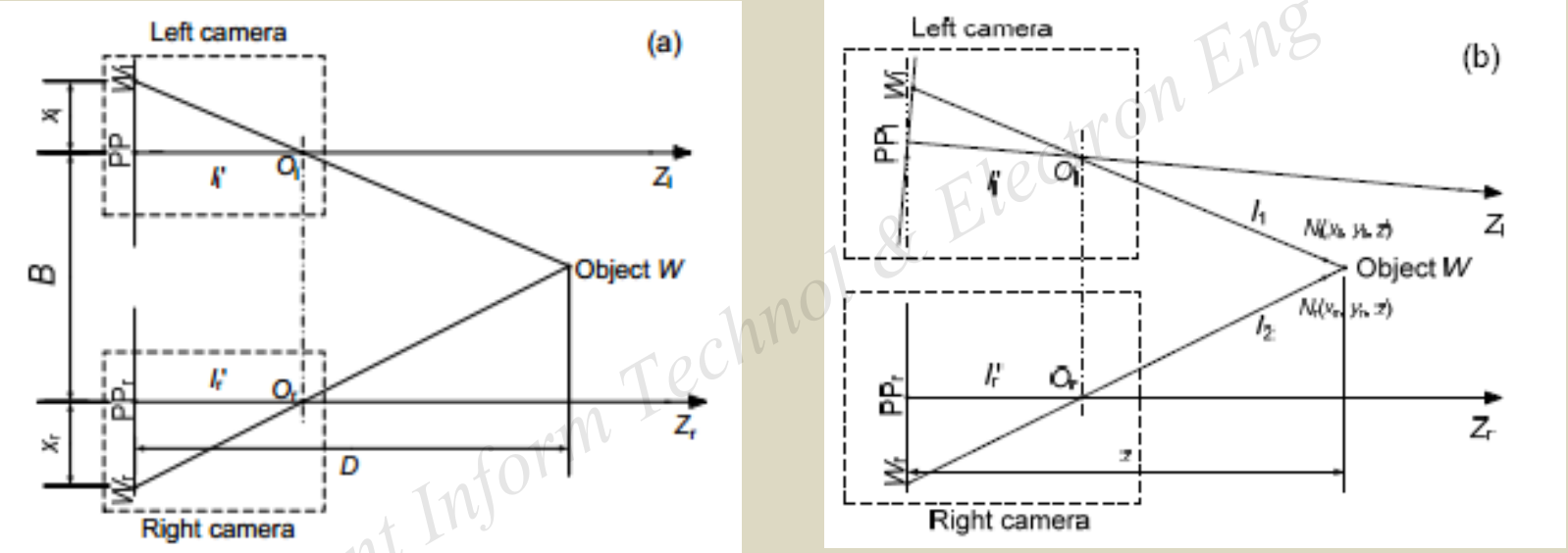


Fig. 1 The optical system of the 3D laparoscope

(a) A view of the optical system including two optical channels; (b) Arrangement of optical cores; (c) A real image of the dual channel optical system

Camera models of laparoscopy



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Fig. 2 Ideal (a) and real (b) camera models of laparoscopy
O_l (O_r) represents the optical center of the left (right) camera; PP_l (PP_r) represents the principal point of the left (right) camera; W_l (W_r) is the left (right) imaging point of object W

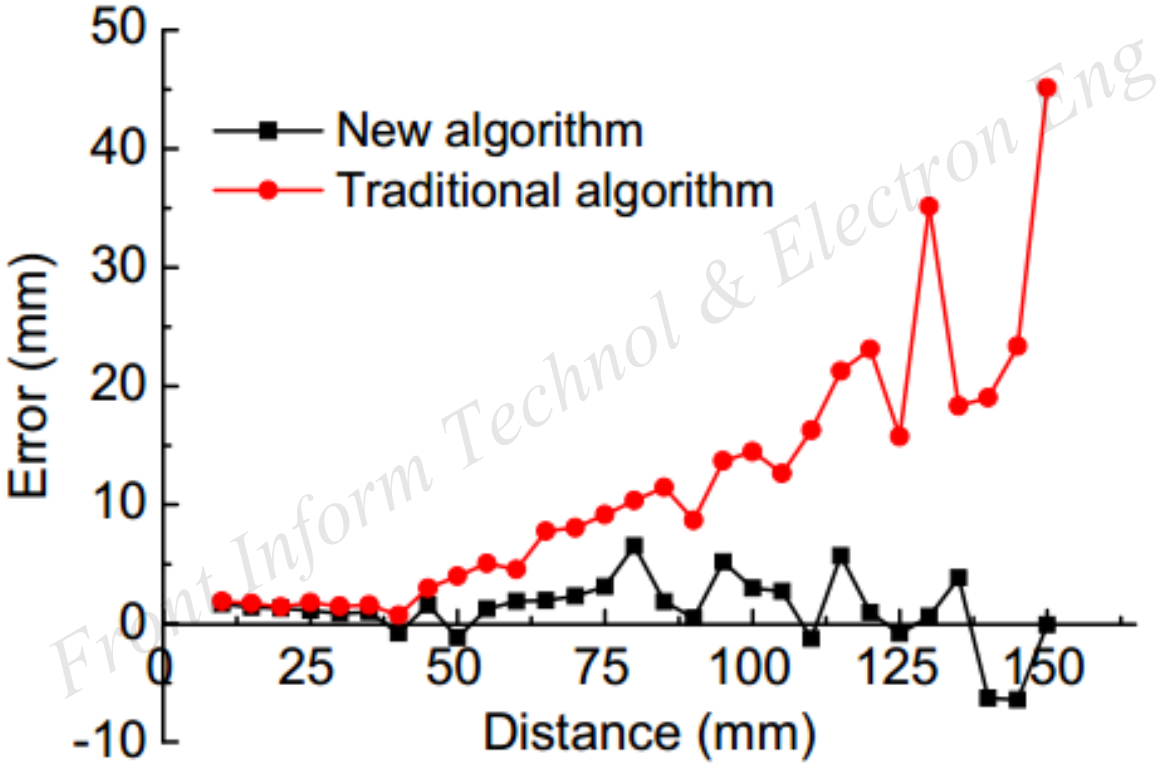
Camera calibration parameters

Table 1 The main characteristics of the laparoscope

Parameter	Left camera	Right camera
Focal length (mm)	1.664	1.673
Principle point (pixel)	(695.7, 455.2)	(681.8, 418.9)
Translation vector (pixel)	(4.43839, 0.86019, 0.14590)	
Rotation vector (pixel)	(−0.00480, −0.00398, −0.00088)	

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Distance measurement results



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Fig. 3 Error curves of distance measurement

HD 3D laparoscopic system

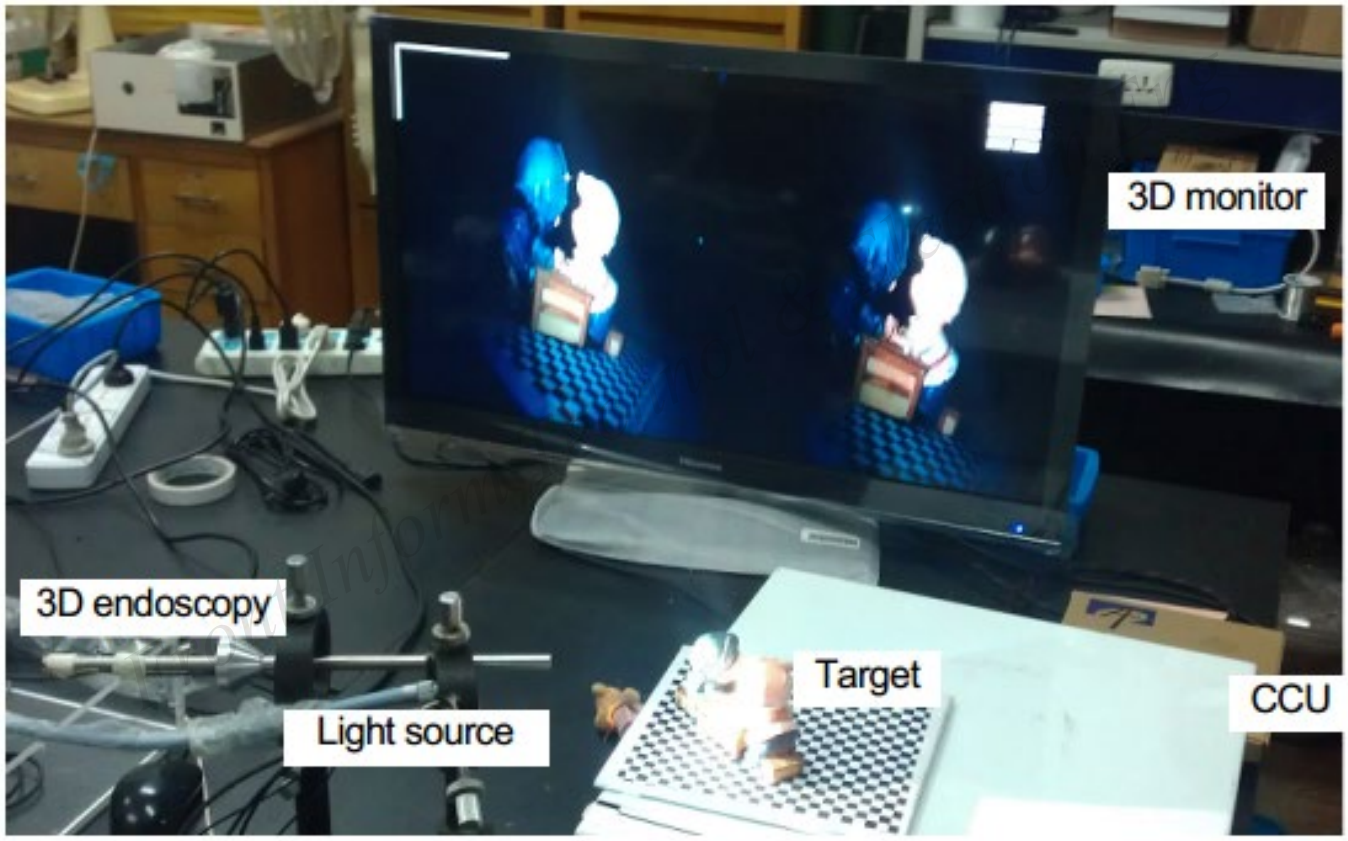


Fig. 4 Brief view of the whole system of the 3D laparoscope

Conclusions

- The HD 3D laparoscope with a simple binocular vision structure has high optical performance including an 80^{o} field of view and less than 3% distortion.
- The specially designed CCU can provided real-time HD video image processing, display an 1080p HD HDMI output.
- A new method of depth measurement for binocular vision is proposed, and the error was less than that by classic stereo triangulation in the experiment.

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