Journal of Applied Science and Engineering Innovation, Vol.5, No.4, 2018, pp.117-120
ISSN (Print): 2331-9062
ISSN (Online): 2331-9070

Three-dimensional Measurement System Design of Binocular Electronic Endoscope

YAN Wei, WU Xiao-qiang

College of Physics and Electronic Information, Inner Mongolia University for the Nationalities, Tongliao 028000, China

Abstract: Three-dimensional measurement technology has progressed rapidly with the wide range of social needs. The three-dimensional analysis of medical diagnosis also forms an important branch of computer vision. Therefore, the three-dimensional measurement system design of the binocular electronic endoscope was studied in manuscripts. Firstly, based on the principle of triangulation, the stereo matching of binocular endoscope is further elaborated. Depth measurement and accuracy analysis were analyzed. Then, the selection of matching constraints and matching primitives are introduced from the perspective of search strategy. From the polar line principle to parallax smoothness constraints, the basic criteria and constraints for solving parallax are analyzed. Finally, the light source and the software processing module are analyzed and the software functions are divided.

Keywords Binocular endoscope; 3D measurement; Structural design; Module analysis

INTRODUCTION

Under the background of the wide application of electronic medical devices, medical electronic endoscopes occupy a very important position in clinical medicine because of their advantages such as high resolution at close range, high definition, and no blind spots in the field of view [Eguchi K et al., 2017]. Through the electronic endoscope, the organ morphology and lesions of the internal organs of the patient are directly reflected in the form of images to the doctor. At present, the widely used endoscope generally acquires two-dimensional scene information. For some body tissues with irregularities, it is difficult to determine the depth information. This may lead to misjudgment for inexperienced doctors, scratches or strains on the soft tissue in the body, which will make the patient experience unbearable pain. Statistics show that even a highly trained and experienced physician has only 90% chance of successfully inserting the endoscope into the distal end of the colon. Therefore, the safety factor of endoscopic surgical operation based on experience alone needs to be improved [Wilhelm P et al., 2016].

With the improvement of people's living standards and the rapid development of medical technology, minimally invasive techniques have become one of the important branches and development trends of modern medicine. This places high demands on the doctor's skill level, experience level, and endoscope data processing system. Thus, an endoscope system with three-dimensional scene display and measurement functions came into being.

Minimally invasive surgery based on a three-dimensional display endoscope system has better results than conventional surgery [Igarashi T et al., 2012]. It can reduce the patient's pain during surgery and shorten the recovery cycle. In addition, medical personnel can take a little training to get on the job, and the operation is simple and easy to analyze. As far as the market is concerned, the market share of three-dimensional electronic endoscopes is gradually increasing. With the continuous enhancement and perfection of functions, the practicality and simplification of the user interface will be very good.

Machine vision-based three-dimensional reconstruction technology belongs to the non-contact category. The non-contact 3D measurement system can measure the measured object at a certain distance from the system. The distance depends on the actual system. Because it does not require contact with objects, it measures faster. According to whether the light source used in the measurement process is divided into active measurement and passive measurement. Among them, the passive measurement achieves three-dimensional data acquisition of the scene through the collected image without the illumination light source. The common method is the binocular measurement technique.

Therefore, a binocular electronic endoscope system based on three-dimensional measurement is designed in this paper. The article first demonstrated the overall scheme of the three-dimensional endoscope system, then analyzed the principle and accuracy of the system's depth of scene acquisition, and finally gave a brief description of the main modules for the specific needs of the system.

Corresponding Author: WU Xiao-qiang, College of Mechanical Engineering, Inner Mongolia University for the Nationalities, Tongliao, 028000, China.

SYSTEM OVERALL DESIGN SCHEME

The three-dimensional measurement medical endoscopic system of binocular stereo vision technology includes an illumination module, an image acquisition display module and a three-dimensional measurement module. The overall structure of the system is shown in Figure 1.

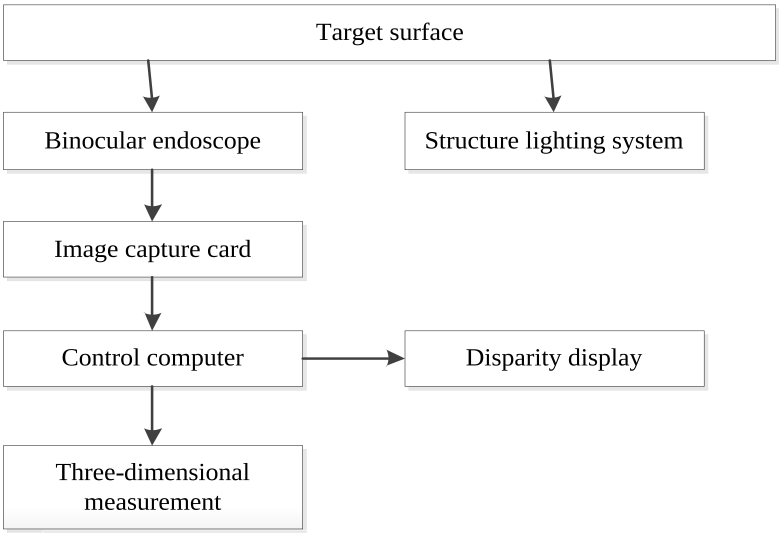

Figure 1 Binocular medical endoscope system block diagram

The entire system consists of lighting system, binocular endoscope, image acquisition card, and computer hardware. The lighting system uses the generated structured light pattern to give the measured object the characteristic information. The binocular endoscopic camera machine acquires tissue optical signals in real time. The image capture card converts analog signals into digital signals and transmits them to the computer via USB. Finally, the computer software analyzes and processes the acquired image pairs to obtain the required three-dimensional information. The workflow of the system is shown in Figure 2.

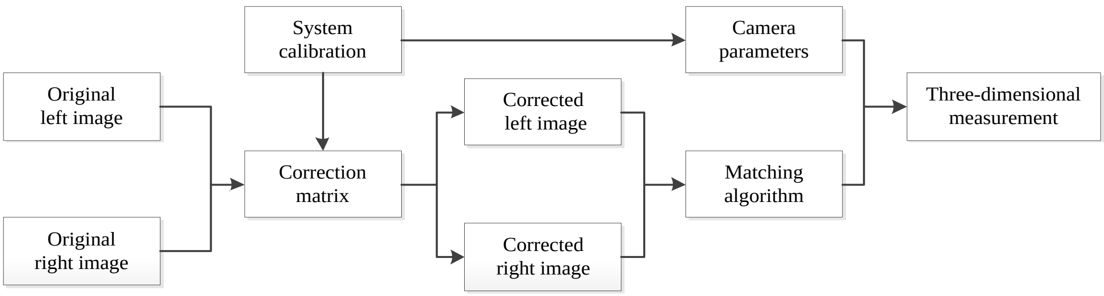

Figure 2 System Workflow Diagram

SYSTEM BASIC PRINCIPLE

Triangular Distance Measurement

Similar to human eyes, computer vision systems are also able to imitate the ability of stereo imaging to a large extent [Duan Z et al., 2017]. The stereo imaging is performed by finding corresponding points on the image pairs captured by the two cameras.

For an undistorted, calibrated binocular system, two cameras ensure forward alignment. That is, the two image planes lie in the same plane, the optical axis remains parallel, and both cameras are fixed. In this way, one pixel row in the left image is perfectly aligned with the corresponding pixel row in the right image.

Depth information values can be derived using similar triangle relationships

$$\frac{T-(x_l-x_r)}{Z-f}=\frac{T}{Z} \tag{1}$$

The corresponding theoretical accuracy can be expressed as

$$\Delta Z=-\frac{fT}{d^2}\Delta d \tag{2}$$

The depth distance is inversely proportional to the disparity value. The farther the measurement depth is, the smaller the disparity value is. This makes the system suitable for measuring close targets, at this time the corresponding measurement sensitivity is high, and has higher measurement accuracy.

Matching Principle

The accuracy of the final depth depends entirely on the accuracy of the matching point. Considering the actual scene application, we only discuss the local stereo matching process. The local stereo matching algorithm uses the parallax calculation of the field of window center pixels. Compared with the sparse disparity map based on feature-based stereo matching algorithm and the high computational complexity based on global matching algorithm, local matching algorithm can obtain dense disparity map in a shorter time.

Matching the basic unit as a small part of the window area, the appropriate choice can improve the accuracy of the match. Matching basic units can be roughly divided into three categories for different scenarios: gray values of image pixels, image feature information, and image content.

Pixel gray value processing for a single pixel gray value is the simplest and most direct means. But at the same time sensitive to the slight differences in the image, poor anti-interference ability. For local area grayscale functions, a feature vector is formed using the pixels within the window. The optimal disparity value is obtained by judging the similarity of two feature vectors. This method is sensitive to the size of the window, large windows will blur the edges, and small windows are more sensitive to noise. Binocular matching based on image content seeks to find an optimal disparity value over the entire image. This method generally operates in an iterative manner. Therefore, to obtain a better disparity map, it takes more time.

Matching Constraints

For two images of the same scene taken from different angles, the more intuitive matching search strategy is for a certain target point in the reference image. In the image to be matched, the pixel with the highest degree of similarity is searched as its matching point. In order to reduce the false matching rate of the target point and improve the matching speed, most of the matching algorithms apply the constraint assumption. These constraints can be divided into two categories based on image geometry and based on the target scene.

The constraints based on image geometry are mainly based on the corresponding geometric relationships in the image acquisition process. This includes uniqueness constraints and polar line constraints [Borkar A et al., 2011]. The uniqueness constraint means that for a certain target point in the matching image, when there is an occlusion problem, there can only be at most one matching point in the image to be matched. When the target is placed vertically with a camera, two or more projection points appear in the image, but the points are separated on the other projection surface. The polar line constraint means that the projection of a point P in the space on the left and right image planes is Pl and Pr. After the camera is calibrated, the correction of the polar line of the image pair can be realized, and then the Pl point corresponds to the point Pr and must be on the polar line. In this way, the potential two-dimensional search space is reduced to one-dimensional and the search matching speed is improved [Borkar A et al., 2011].

The constraints based on the target scene are the inherent properties of the shape of the target object in the scene and their mutual correspondence. In most cases, the disparity is continuously changing for space targets where the angularity is not very clear. This satisfies parallax smoothness constraints. However, this constraint does not hold for the edge of the object. For two images of different perspectives in the same space, there is a maximum parallax value. By artificially specifying this value and limiting the search matching point range, matching reliability can be improved.

SYSTEM MAIN MODULE

For the weak texture or repeated texture region in the scene, the current stereo matching algorithm cannot give a better scene disparity map. For the inherent attributes of this goal, the problem can be solved fundamentally by providing features. Among them, in order to achieve the characterization of the target scene, the corresponding feature information needs to be projected. The use of a conventional projector will inevitably have a large space requirement for the structure, and it is difficult to realize the reality in the narrow space of a real three-dimensional endoscope. For this reason, it is necessary to design a lighting system that can make the structure as compact as possible while generating features.

The software is mainly divided into display and control modules. The structure is shown in Figure 3.

In the display module, two-dimensional binocular images are displayed in real time. When stereo matching is performed, the scene depth parallax map is pseudo-color displayed, and when the video is frozen, a three-dimensional scene map at this moment can be given. The control module mainly processes the camera and the captured image, and involves basic operations such as camera exposure, gain adjustment, image saving, video saving, and video freeze.

CONCLUSION

Stereo vision measurement is a kind of non-contact three-dimensional measurement. With the development of related hardware and stereo matching algorithms, it has absolute advantages in terms of cost, volume, and other measurement methods. Therefore, it has been widely used in medical, industrial and other fields. This paper first introduces the composition of the entire three-dimensional measurement system, and then elaborates the principles of stereo vision measurement and the main modules of the system. Considering the effect of the laser's color information on the measurement scene, the color of the laser must be further studied and tested in the actual medical environment.

ACKNOWLEDGMENT

REFERENCES

Borkar A, Hayes M, Smith M T. Polar randomized hough transform for lane detection using loose constraints of parallel lines [C] IEEE International Conference on Acoustics, Speech and Signal Processing. IEEE, 2011:1037-1040

Borkar A, Hayes M, Smith M T. Polar randomized hough transform for lane detection using loose constraints of parallel lines [J]. 2011:1037-1040.

Burgette L F, Mulcahy A W, Mehrotra A, et al. Estimating Surgical Procedure Times Using Anesthesia Billing Data

and Operating Room Records [J]. Health Services Research, 2017, 52(1):74-92.

Duan Z, Yu Y, Gao B, et al. Absolute distance measurement based on multiple self-mixing interferometry [J]. Optics Communications, 2017, 389:270-274.

Eguchi K, Wongjan A, Julsereewong A, et al. A median filtering circuit using clocked CMOS neuron inverters for implantable electronic medical devices [J]. International Journal of Innovative Computing Information & Control Ijicic, 2017, 13(4):1135-1147.

Igarashi T. Editorial comment to new three-dimensional head-mounted display system, TMDU-S-3D system, for minimally invasive surgery application: procedures for gasless single-port radical nephrectomy [J]. International Journal of Urology, 2012, 19(9):890-890.

Srejic U, Larson P, Bickler P E. Little Black Boxes: Noncardiac Implantable Electronic Medical Devices and Their Anesthetic and Surgical Implications[J]. Anesthesia & Analgesia, 2017, 125(1).

Schneider Z, Shahbazian J, Krishnan S M. Assessment of Distance Measurement with Selected Wearable Devices in Telemonitoring [C] Biomedical Engineering Conference. IEEE, 2016:5-6.

Wilhelm P, Axt S, Storz P, et al. Pure Natural Orifice Transluminal Endoscopic Surgery (NOTES) with a new elongated, curved Transanal Endoscopic Operation (TEO) device for rectosigmoid resection: a survival study in a porcine model [J]. Techniques in Coloproctology, 2016, 20(5):273-278.