Development of 3D FULL HD Endoscope capable of scaling view of the selected region

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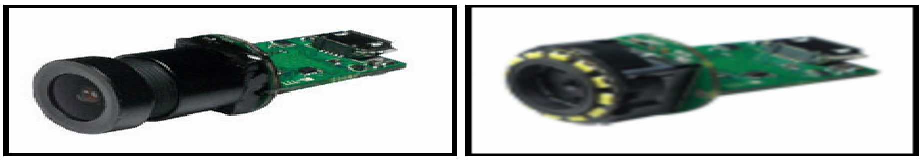
Abstract. The stereo vision ability of human beings enables the surgeon with depth perception and thus can allow for organ localization in human body. In this work, we propose an approach of developing a 3D prototype for stereo endoscopes. The stereo calibration and rectification processes have been implemented in order to nullify the effects of lens distortions. The processed output was in interlaced format and can be visualized in 3D format on a passively polarized monitor using polarized glasses. The proposed system also provides the snapshot, video write and retrieval in individual left and right streams along with live process display. The scaling feature provides a detailed view of the selected region of interest.

Keywords: Stereo, Endoscope, Stereo Calibration, Image Rectification, Depth, Lens distortion, Passive Polarization, Full High Definition.

1 Introduction

The modern advancements in the display devices has modified the facilities in the form of tools in a dynamic and remarkable way for surgical applications. Earlier known techniques such as MRI allows for an approximation view of the patient organs without providing their localization information to the surgeon along with their radiation hazards. The surgeon has to perform the surgery using long incisions and it leads to long recovery times of patients and risks of infection also. To solve this problem, the 2D endoscopes had been used which helps in performing surgery using small incisions but it lacked depth information and also suffers from image distortion effects[1]. The lack of depth perception in the observed scene earlier made the endoscopy less effective. The human anatomy requires depth perception by the surgeon in order to make the surgery more effective and result oriented.

Many researchers had used different techniques for retrieving depth information from the images. In robot assisted surgery, ultrasound images had been used for 3D reconstruction[2]. The Computer Aided Surgery (CAS) software had also been used for decreasing errors of clinical after effects. The depth information was simulated by using imaging algorithms by regnerating the stereo data from two separate video stereams. In this article, a prototype of a Real Time FULL HD Stereo System using Misumi sensors as shown in Figure 1 has been demonstrated.



(a) MD-B5014-3.0 with Manual Focus (b) Misumi FULL HD Miniature Camera

Fig. 1: Misumi FULL HD Miniature Camera[3]

The Misumi MD-B5014-3.0 and Misumi MD-B5014LV-3828 have been used for making the stereo rig for the endoscope.The camera are very small in size with a foot print of 14 X 26 mm only as shown in Figure 1. In earlier attempts, the 3D was visualized using active shutter glasses by surgeons but it mostly leads to headache, fatigue and nausea[4]. In place of this, the proposed system uses light weight passive polarized glasses with no after effects.

The article consists of six sections. The concept of stereo Imaging is described in section 2. The design of stereo system is discussed in section 3. The section 4 covers the logic implementation. Results and Analysis are described in section 5. Section 6 contains the conclusion of the research work.

2 Stereo System Design

A prototype of 3D endoscope has been developed with added features in the form of snapshot, video read, write and real time zoom and unzoom facility. The stereo assembly using the Misumi miniature cameras is shown in Figure 2.

(a) Stereo Rig with 3D Scope [5] (b) Stereo Assembly

Fig. 2: Stereo Endoscope System

The stereo system receives the video output of left and right cameras simultaneiously. The captured frames were used to perform the stereo calibration[6]and rectification. The rectified right and left images were used to form the combined image having even and odd scan lines from right and left images and this process is called as interlacing. Another version of stereo rig was also designed which has auto focus and 10 white LED's mounted on the sensor itself to illuminate the view homogenousely as shown in Figure 3.

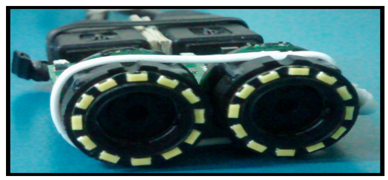


Fig. 3: Misumi MD-B5014LV-3828 Stereo Assembly with mounted LED

It can capture frames at a maximum resolution of 5.0 M i.e. 2592 x 1944/ 15 fps or FHD i.e. 1920 x 1080 at 30 fps.The Final stereo endoscope with Full HD capture capability is shown in Figure 4.The Viking Systems dual channel 3D Endoscope was used for the proposed work as shown in Figure 4. The working length was 415mm with diameter of 10mm and field of view as 75°. The Misumi MD-B5014-3.0 as shown in Figure 4 was used to form a stereo assembly.

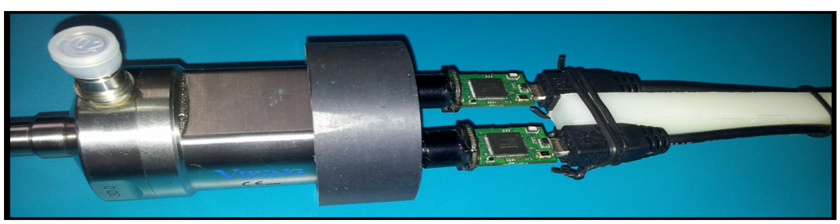


Fig. 4: Stereo Endoscope Assembly with sensors interfaced

The sensors data was captured and transferred to computer using 2 mini USB connections.

3 Logic Implementation

The stereo endoscope produces in contrast to mono scopes[7] two individual streams of video simultaneously from the sensor. To generate the 3D output from them stereo calibration and rectification needs to be performed on captured data to compensate for the errors and defects in sensors and processes used.

3.1 Stereo Calibration

It is an essential step in stereo vision, so as to generate the metric data from left and right two dimensional images. It was used to compute three types of parameters i.e. camera intrinsic parameters, camera distortion parameters and extrinsic parameters[8]. A checkerboard pattern is used for this step as it has many identifiable points in the form of corners which were successfully detected[9].

3.2 Stereo Rectification

The stereo rectification was used to re-project the two cameras image planes such that they lie in the forward equivalent formation. First, the images were re-projected and then alignment of the two images in the same line was done[10]. The hartley[11] and bouguet [12] algorithms were tested for stereo rectification and due to the promising results of bouguet algorithm, it is used for the final prototype implementation.

3.3 Interlaced View Generation

Interlacing is a three dimensional display technique used for converting two frame data into single frame at the cost of loss in resolution[13]. The resultant image as shown in Figure 5 contains half number of scan lines from left frame and half number of scan lines from right frame.

Fig. 5: Interlaced 3D output

This process requires the viewing glasses to be of same polarization as the display screen as shown in Figure 5. The passively polarization technique was used to project and view the 3D image on viewers eye.

3.4 Zoom view Generation

Zooming is the process which was used, to increase the number of pixels by scaling an image area X of (width*height) data elements by a scaling factor F, so that the image appears larger. The zooming can also be called as scaling of an image. Various methods are reported in literature for zooming like nearest neighbor interpolation[14], bilinear interpolation[15], bi-cubic interpolation[16], k-times interpolation etc. The illustration of the zooming is given in Figure. 6.

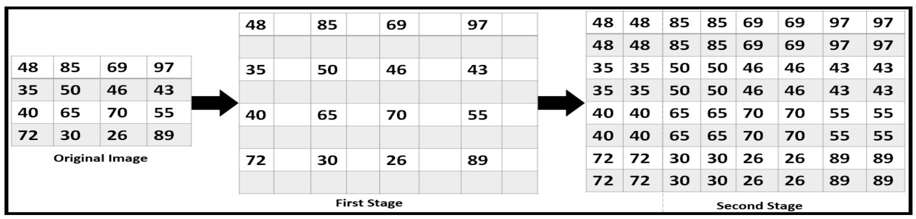


Fig. 6: Zoomming process

The K-Times interpolation technique was used for zooming process due to its promising results. The flowchart explaining the sequence of steps for the algorithm is given in Figure 7.

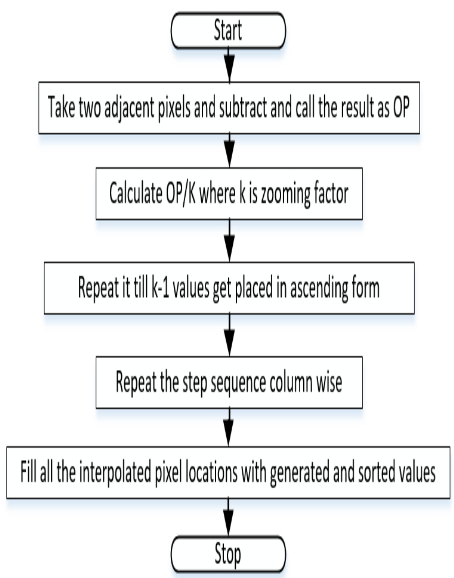


Fig. 7: flowchart for zoomming technique

The K-times interpolation technique was used for zooming algorithm. First row wise zooming was done followed by columns wise zooming.

The dimensions of the new image will be as given in eq.(1).

$$\{K * (numberofrows - 1) + 1\} * \{K * (numberofcolumns - 1) + 1\} \qquad (1)$$

For an source image of 2 rows and 3 columns as shown in Figurre 8(a) consider k =3 i.e. zooming factor is 3. The number of values that should be inserted are equal to k-1 i.e. 3-1= 2. The destination image as obtained after row and column wise zooming is shown in Figure 8(b).

25	55	25
55	25	55

(a) Source Image

25	35	45	55	45	35	25
35	38	38	35	41	38	35
45	41	41	45	38	41	45
55	45	35	25	35	45	55

(b) Destination Image

Fig. 8: Source Image and Destination Image

4 Results

The technique provides the flexibility of slecting a Region of Interest (ROI) as shown in “render” window of Figure 9, which then acts as input to zooming algorithm. The output of the zooming technique is shown in Figure 9.

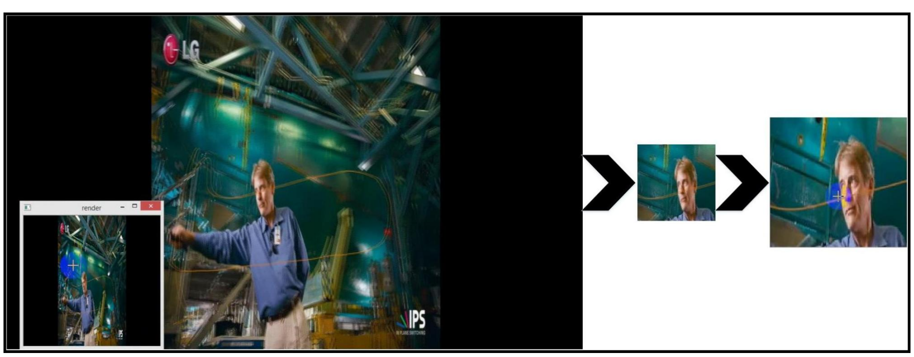


Fig. 9: ZOOM operation on Real Time stereo output

According to the fixed value of "K", the dimensions of the output image were calculated and the intermediate pixel values were evaluated in row followed by column fashion. The algorithm has been successfully implemented using FULL HD Misumi sensors and real time 3D output has been obtained and displayed on a passive polarized monitor. The algorithm process the left and right video streams by first performing stereo calbration followed by rectification. The remapped data was then used for interlace output generation which was viewed in 3D form using polarized glasses.

5 Conclusions

The proposed interlaced based 3D stereo technique has been developed for the robotic assisted surgical applications where a scope is inserted in patient's body and the stereo cameras are used to form a 3D view of internal organs. The proposed method can generate real time FULLHD output from misumi's miniature cameras. The additional features provided on its API in terms of snapshot capture, 3D video storage,left and right video read and write option, live display of running process and real time zooming and unzooming makes the technique more appealing and product oriented. The passive polarized monitor provides a 3D output using economically priced passive glasses.

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