AUTO-FOCUSSING OF AN ENDOSCOPIC LASER USING IMAGE TRACKING WITH AN ENDOSCOPIC ROBOT

Hsiao-Wei Tang*, Hendrik Van Brussel*, Philippe Koninckx**,
Jos Vander Sloten***, Dominiek Reynaerts*

*Division PMA, Deptartment of Mechanical Engineering,
**Department of Obstetrics and Gynecology, University Hospital Gasthuisberg,
***Division BMGO, Department of Mechanical Engineering,
Katholieke Universiteit Leuven, Leuven, Belgium

Abstract: **This article describes the methods to extract the distance information in endoscopic laser surgery and from which to control the laser to maintain its focused position automatically when manipulating it by means of the intuitive pen interface developed by the authors.**

Keywords: **Image-processing, endoscope, CO_2 Laser**

Introduction

We have developed an intuitive interface for use in robot endoscopic laser surgery [1]. By the innovative integration of a drawing tablet and a wireless pen to control the robot, a surgeon can use his/her familiar drawing skill to easily manipulate the laser beam to track and point and ablate at will. However, the 2D-interface can only steer the laser beam on a spherical surface with the trocar point as its centre. The third axis that slides the endoscope in/out the trocar is also very important and must be taken into account during the operation. In endoscopic laser surgery, it dominates the focusing of the laser as well since the laser is coupled to the endoscope. Therefore, in order to obtain the highest energy concentration for good cutting quality, the (automatic) control of the sliding axis is essential.

The key issue in endoscopic laser surgery is the distance from the tip of endoscope to the soft tissues. Since suitable distance sensors do not exist, an alternative method to estimate the distance has been developed and is presented here. Using appropriate image-processing algorithms, the distance is extracted and fed to the robot axis controller to automatically focus the laser. The combined intuitive interface and auto-focussing functions significantly enhance the surgeon's skill and ability to perform high-quality and char-free precision laser cutting.

Materials and Methods

The specific endoscope for laser surgery used in this research provides two thru-channels: one for vision and illumination and the other for transmitting the laser beam. As can be seen from figure 1, the centerlines of the lens and the laser beam are parallel in space. If the lens distortion can be neglected, the distance δ can be assumed constant.

The size of the area of soft tissues projected on the screen is inversely proportional to *d*. By using triangulation, the distance δ_s between the laser spot and the centerline on the screen is inversely proportional to *d*. Via this relationship, we can estimate the distance *d* by acquiring the spot position on the image.

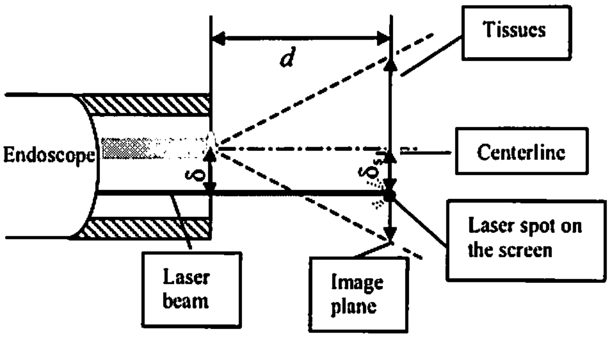

Figure 1. Endoscope distance sensor

Figure 2 shows the scheme of the auto-focus function. We use a Picasso frame grabber to acquire the images from the camera and a dSPACE DSP card to control the motion of the in/out sliding axis. VC++ is the software development platform used to realize the scheme.

In order to activate the auto focus function, the distance must be monitored continuously. According to the described method, we set the centerline point on the image by moving the lens far away from the surface where the laser spot will approximately coincide with centerline point. Then, we acquire the image from the camera by the frame grabber and implement the Cam-

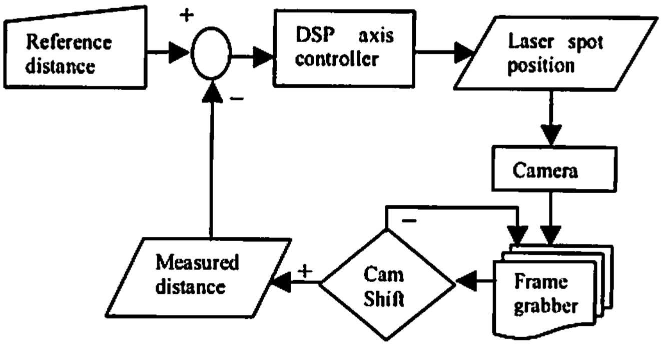

Figure 2. Scheme of the auto- focussing functionality

shift algorithm [2] to track the laser spot on the grabbed image. The Camshift algorithm from the Open Source Computer Vision Library is designed to find the center and size of the colour object by operating on the colour probability image. We take the red He-Ne laser spot as the feature to be extracted from the image. By applying this algorithm, the measured distance δ_s between laser spot and centerline point on the image is derived and can be used for motion control.

The reference distance between laser spot and centerline point is recorded and verified by the surgeon by manually focussing the laser. Then, the closed-loop DSP controller maintains the laser in focus by comparing the measured distance with the reference distance.

Results

The system has been set up successfully and performs well. The maximum update rate of the control loop is about 7 Hz. Initially, surgeons are asked to manually steer the laser to its focus position. Then the reference distance and colour model of the HE-Ne laser spot are recorded in the memory by selecting the laser spot position in the window. Subsequently, the program starts the image-processing procedure to perform auto-focussing whenever the laser and endoscope are steered by the intuitive interface. The program allows the surgeon to observe directly the tracking of the laser spot. As a safety measure, the sliding axis is blocked when the tracking is malfunctioning. The test is performed on a mono color background since the color is the important feature for the image-processing algorithm. The maximum speed of the sliding axis is presently limited to about 10mm/s, which may not be sufficient enough in fast movement cases. However, it is safe and working well for slow movements like required for precision cutting. Figure 3 show the characters PMA, 3mm×3mm, cut on an apple. It demonstrates the significant advantages of the implementation of the intuitive interface and the auto-focus functions applied in endoscopic laser surgery.

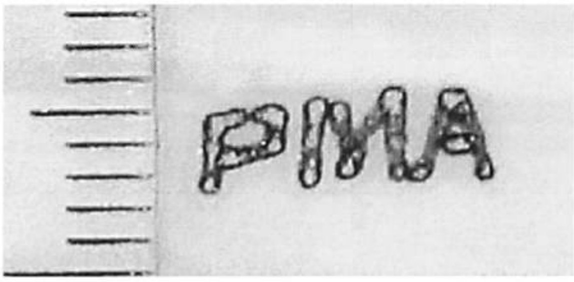

Figure 3. Cutting characters in an apple using intuitive interface (scale in mm)

Discussion

Since it is difficult to find a suitable distance sensor, we applied the relationship between the spot position on the screen and the distance to the tissues to measure the distance between lens and tissues. It serves as a distance sensor in the control loop. Although the distortion of lens affects the linearity of the sensing output in the described method, there is no need to calibrate the distortion. The reason is that, since the reference distance is the demanded output, the distortion level is the same when the laser is in its focus position. Therefore the reference distance will not vary in the whole procedure. Besides, it is possible to calibrate the effects in order to get a more accurate distance if necessary.

The system can only measure the perpendicular distance of the image plane since the centerline and laser beam are parallel. We can see from figure 4 that the auto-focusing is still working when the tissue is under an angle with respect to the image plane, as long as the angle is not too big.

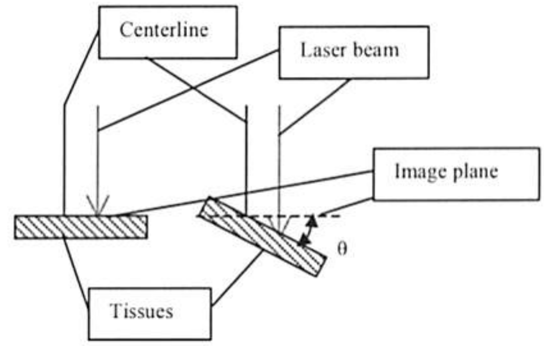

Figure 4. The orientation of soft tissues' surface

The image-processing algorithm we used now only separates the red spot on a white background. It is not suitable in real environments, especially inside he human body. Therefore, the programme capabilities must be extended to make it usable in real-life surgical environments.

Conclusions

A practical methodology is described to estimate the approximate distance between the endoscope and the soft tissue. The auto-focussing control loop uses the extracted distance information and some image-processing algorithms to control the in/out axis of the robot. An experiment demonstrates the excellent performance of the system, programmed by an intuitive writing interface. The complete system will enhance the surgeon's capabilities in endoscopic surgery.

Acknowledgement.

REFERENCES

[1] H. W. Tang, H. Van Brussel, P. R. Koninckx, J. Vander Sloten, "The implementation of an intuitive man-machine interface in robot-aided endoscopic laser surgery", in CARS Proc. of 16th Int. Congr. and Exhib., Paris, 2002, pp.200-205

[2] G. R. Bradski, "Computer vision face tracking for use in a perceptual user interface", Intel Technology Journal Q2, pp.1-15, Apr. 1998.