A New Algorithm for the Visual Tracking of Surgical Instruments in Robot-assisted Laparoscopic Surgery

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***Abstract*—We proposed a novel algorithm for instrument segmentation in the robot-assisted laparoscopic surgery (RALS) images, which will be used for tool tracking to automatically preventing hazardous situations. The proposed algorithm achieved 1mm range of average RMSE of tool tip position in various conditions, which is significantly lower value compared to the previous methods.**

I. Introduction

The use of robot-assisted laparoscopic surgery (RALS) has been growing over the past years rapidly. RALS has various advantages such as smaller incisions and thereby shortened recovery time. Nevertheless, due to the limited field of view and the absence of haptic feedback, there exists some chance of exerting unintended excessive force on fragile tissue by the instruments. To automatically prevent this type of unwanted situation, vision-based instrument tracking algorithm has been sought [1].

Although previous approaches based on color characteristics, geometric information and/or tool shape classifiers achieved partial success in automatic tool detection, all those algorithms exposed limitation such as intermittent loss of tool tip information under typical time-varying illumination conditions[2]. In this study, we proposed an improved automatic tool detection algorithm and verified its applicability in test images.

II. Methods

The proposed algorithm consists of several steps of image processing as shown in fig. 1, among which so-called background simplification step is the most efficient way to remove noise from the images. Performance of each method was compared by the RMSE between the calculated tool tip position and the true position measured manually[3]. 70 sec-long test images were constructed using 10 sec video clip having 3 instruments in 7 different surgical situations including bleeding, smoking and illumination flickering.

*Research was supported by the Industrial Strategic Technology Development Program, (10035145, Development of Multi-arm Surgical Robot for Minimally Invasive Laparoscopic Surgery) funded by the Ministry of Knowledge Economy, Korea.

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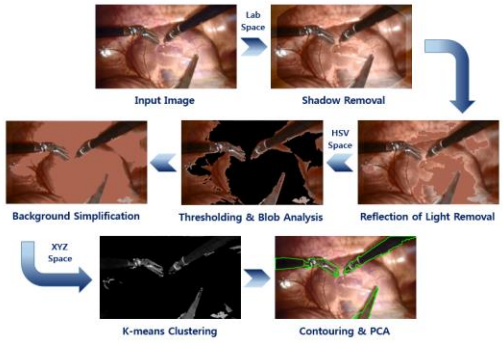
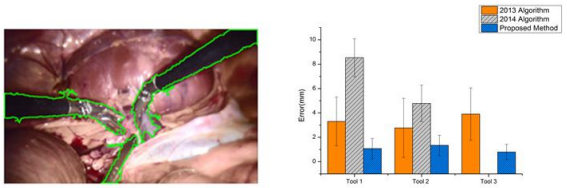


Figure 1. Image processing procedures in the proposed algorithm

III. Results

As shown in Fig. 2(a), the proposed method clearly segments out three instruments. The RMSE values of the tip position are 1.07±0.83mm, 1.34±0.83mm, 0.08±0.63mm for the tool #1, #2, and #3, respectively, which represents significantly smaller average as well as SD of error compared to the other two previously published methods.



(a) (b)

Figure 2. (a) Typical result of surgical instrument segmentation and (b) RMSE (average and SD) values of tool tip position for the proposed algorithm in comparison with other two previous algorithms.

IV. Discussion & Conclusion

Vision-based surgical instruments' position detection is expected to play an important role in the realization of automatic prevention of possibly hazardous conditions such as tool collision and unintended tissue damage. In conclusion, the proposed instrument segmentation algorithm is a good candidate for the automatic tool tracking which can be usefully applied to the detection of emergency situations during robot-assisted laparoscopic surgery.

References

[1] Ryu, JW, Choi JS, Kim HC. *Endoscopic vision-based tracking of multiple surgical instruments during robot-assisted surgery*. Artif Organs 2013; 37(1):107-112.

[2] Baek YM, Tanaka S, Harada K, Sugita N, Morita A, Sora S, et al.

Robust Visual Tracking of Robotic Forceps Under a Microscope Using Kinematic Data Fusion, Mechatronics,IEEE/ASME Transactions on, 2012 Dec; 19(1):278-288
[3] Zhou J, Payandeh S. *Visual Tracking of Laparoscopic Instruments.* Journal of Automation and Control Engineering 2014 Sep; 2(3)