Vision-guided State Recognition for Automatic Danger Warning in Robotized Laparoscopic Surgery

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Purpose

In the robot-assisted laparoscopic surgery, lack of tactile feedback is the main difficulty to be overcome. Visual feedback is the only information available and so visually being aware of whole surgical environment is critically required of surgeon for safe surgery [1-2]. However, not many studies on the warning system based on state recognition have been actively explored. To increase reliability of the robotized laparoscopic surgery, computer vision techniques can be applied for automatic recognition of the current surgical state. In this paper, vision-guided real-time state recognition is addressed in terms of warning alarms of surgical tool's getting into the predetermined dangerous region.

Methods

Vision-guided real-time state recognition was implemented by tracking the current surgical tool position as well as the preselected prohibited region. As a reference, the center point of a selected tool was manually traced. For automatic tool tracking, fast color segmentation was performed using the k-means clustering and the binarization techniques. Then, the Kalman Filtering (KF) was applied for diminishing tracking disturbances influenced by the background noise and tool motion. KF offers a few advantages through explicit modeling of the uncertainties associated with the proposed models of tool motion and position measurement. For tracking a predetermined prohibited region, the region of interest (ROI) was cropped from the first image and sequentially template-matched to the following images combining the sum of square difference (SSD) and the FFT-based normalized cross correlation (NCC) which is immune to time-varying fluctuation of background. To warn the surgeon of the surgical robot tool unintentionally intruding dangerous region, red light located on the top-left of the display flashes as visual feedback when the tool is approaching the safety boundary of the ROI.

Results

The proposed method showed an acceptable performance in tracking a tool when tested with actual video data as shown in Fig. 1. Fig. 1 confirms the efficiency of the KF in tool tracking by showing reduced peak estimation errors, which implies that the proposed algorithm is more robust to fluctuating background noise and clutter.

An ROI as preselected prohibited region is also traced by SSD and NCC algorithms within a reasonable error range. As in Fig. 2, if the estimated tool position is within approximately ±3cm from the ROI, red light flashes on the image for visual warning feedback.

Conclusion

We have presented preliminary results of a vision-guided real-time state recognition for prohibition of a surgical tool entering preselected dangerous region. With the increased accuracy and reliability of tool tracking, we have enhanced the visual feedback in a computer-aided surgical robotic system. This system will require, among other things, 3D localization of the tool position and boundaries of the ROI.

References

[1] Richa R, Poignet P, Liu C, "Three-dimensional Motion Tracking for Beating Heart Surgery Using a Thin-plate Spline Deformable Model." *Int. Jour. Robotics Research*, 2010. vol. 29, pp. 218-230

[2] Blum T, FeuBner H, Navab N, "Modeling and segmentation of surgical workflow from laparoscopic video." In *Proc. MICCAI'10* Springer: Verlag Berlin, 2010. pp. 400-407

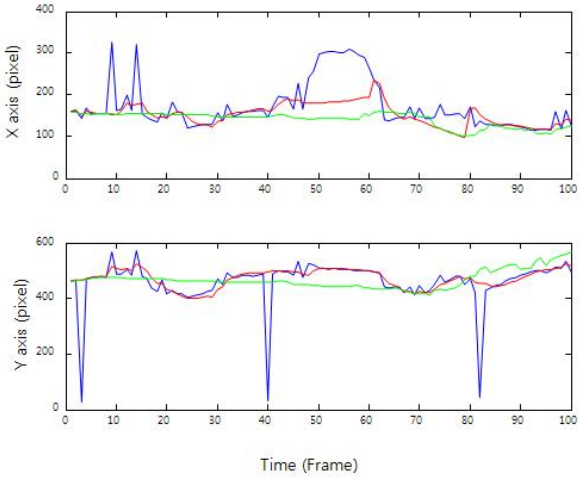

Fig. 1. Comparison among manually traced (green) and automatically estimated center points using k-means clustering and binarization (blue) and additional KF (red) algorithms of the surgical tool as shown in Fig. 2.

Fig. 2 Warning alarm of flashing red light when the surgical tool is within the safety boundary of the selected ROI.