A Hybrid YOLOv8 and Instance Segmentation to Distinguish Sealed Tissue and Detect Tools' Tips in FLS laparoscopic box trainer

Mohsen Mohaidat
Department of Electrical & Computer Engineering
Western Michigan University
Kalamazoo, Michigan
mohsen.mohaidat@wmich.edu

Janos L. Grantner
Department of Electrical & Computer Engineering
Western Michigan University
Kalamazoo, Michigan, USA
janos.grantner@wmich.edu

Saad A Shebrain
Department of General Surgery, Homer Stryker M.D. School of Medicine, Western Michigan University
Kalamazoo, Michigan, USA
saad.shebrain@med.wmich.edu

Ikhlas Abdel-Qader
Department of Electrical & Computer Engineering
Western Michigan University)
Kalamazoo, Michigan, USA
ikhlas.abdelqader@wmich.edu

Abstract*—Intracorporeal suturing is one of the most crucial skills in the Fundamentals of Laparoscopic Surgery. Surgical residents are evaluated by their supervisory surgeon, but surgical assessment demands a substantial amount of time from the surgeons and can result in biased evaluations. In addition, distinguishing sealed tissue among multiple trainees would be a subjective decision. Therefore, we propose an autonomous assessment support system, which can supervise the execution of the suturing task by using YOLOv8 instance segmentation and object detection, tracking the tip of the suturing instruments and monitoring tissue seals and knots. We used mean average precision and inference time metrics to evaluate the performance of the instance segmentation for our proposed suturing assessment system. It was found that the precision of all suturing instruments was 95% and that the mask precision of the tissue was 98.8%. Our proposed autonomous laparoscopic training system saves the supervisor surgeons' time, and the outcomes of the proposed methodology may also be utilized in the development of surgical robots.

I. Introduction

To perform laparoscopic surgeries, surgeons must be capable to carry out suturing, injecting, anastomosing, inserting needles, and a variety of other laparoscopic training exercises [1], [2]. Thus, laparoscopic surgery training programs have been introduced in hospitals. There has been a growing number of surgical simulators developed to enhance surgical skills necessary for complex surgical procedures, as well as to support residency training and improve surgical competency [3]. Here, we discuss methods for analyzing the intracorporeal suturing task to determine the number of knots formed, localize the instruments' tips, and distinguish the tissue status (i.e., sealed, partially sealed, and unsealed) using object detection to evaluate suturing effectiveness.

II. Results

We propose to employ an open-source deep learning algorithm (i.e., YOLO) to detect intracorporeal suturing instruments in an Fundamentals of Laparoscopic Surgery (FLS) box trainer. The workflow of the proposed work is given in Figure.1. We established a new laparoscopic box trainer dataset consisting of frames extracted from various laparoscopic intracorporeal suturing training videos to train the segmentation model.

As the wound must be sealed after every surgery, the intracorporeal suturing task is intended to familiarize resident doctors with multiple laparoscopic procedures [4]. The trainee surgeon must deliver a fully sealed tissue to complete the experiment, and the knots should not become loose. An illustration of the knot-tied tissue is shown in Fig. 2, where the tissue was sealed. A seal is determined based on the size of the tissue, the number of knots, the location of the instruments, and the knots' positions concerning the tissue. As shown in Fig. 2 (b and c), the knot dissociates the tissue from the middle, which indicates that all knots were done as required and the tissue is fully sealed.

Fig. 2 (a) illustrates the top view of the tissue and knot segmentation to classify the tissue status and track how many knots were formed. There are three classes of tissue status, Unsealed Tissue, Sealed Tissue and Partially Sealed. Analyzing the binary mask sizes of the tissue shows significant differences in size between tissue deformation states. Tissue size is measured by considering that the location of other instruments is not touching the tissue to ensure that its size is only affected by the thread knots. In order to achieve a highly accurate size measurement, high detection precision is required. Table I shows that each class ID's average mask precision (AP) represents mask Intersection over Union (IoU) for evaluating segmentation accuracy. The fused instruments' tip positions from both the side and top views are used to track their location accurately. In Fig. 3, the bottom-right corner of the detected left-grasper bounding box and the bottom-left corner of the right-grasper bounding box represent the L-Grasper's tip and the R-Grasper's tip, respectively. From the proposed method and results, several surgical metrics were measured in order to develop an autonomous assessment system to evaluate the surgeons' performance.

References

[1] A. Chellali *et al.*, "Achieving interface and environment fidelity in the Virtual Basic Laparoscopic Surgical Trainer," *Int. J. Hum. Comput. Stud.*, vol. 96, pp. 22–37, 2016.

[2] D. Oh *et al.*, "Surgical techniques for totally laparoscopic caudate lobectomy," *J. Laparoendosc. Adv. Surg. Tech.*, vol. 26, no. 9, pp. 689–692, 2016.

[3] V. Lahanas, E. Georgiou, and C. Loukas, "Surgical simulation training systems: box trainers, virtual reality and augmented reality simulators," *Int. J. Adv. Robot. Autom.*, vol. 1, no. 2, pp. 1–9, 2016.

[4] F. R. Fathabadi, J. L. Grantner, S. A. Shebrain, and I. Abdel-Qader, "Surgical Skill Assessment System Using Fuzzy Logic in a Multi-Class Detection of Laparoscopic Box-Trainer Instruments," in *2021 IEEE*

International Conference on Systems, Man, and Cybernetics (SMC), 2021, pp. 1248–1253. doi: 10.1109/SMC52423.2021.9658766.

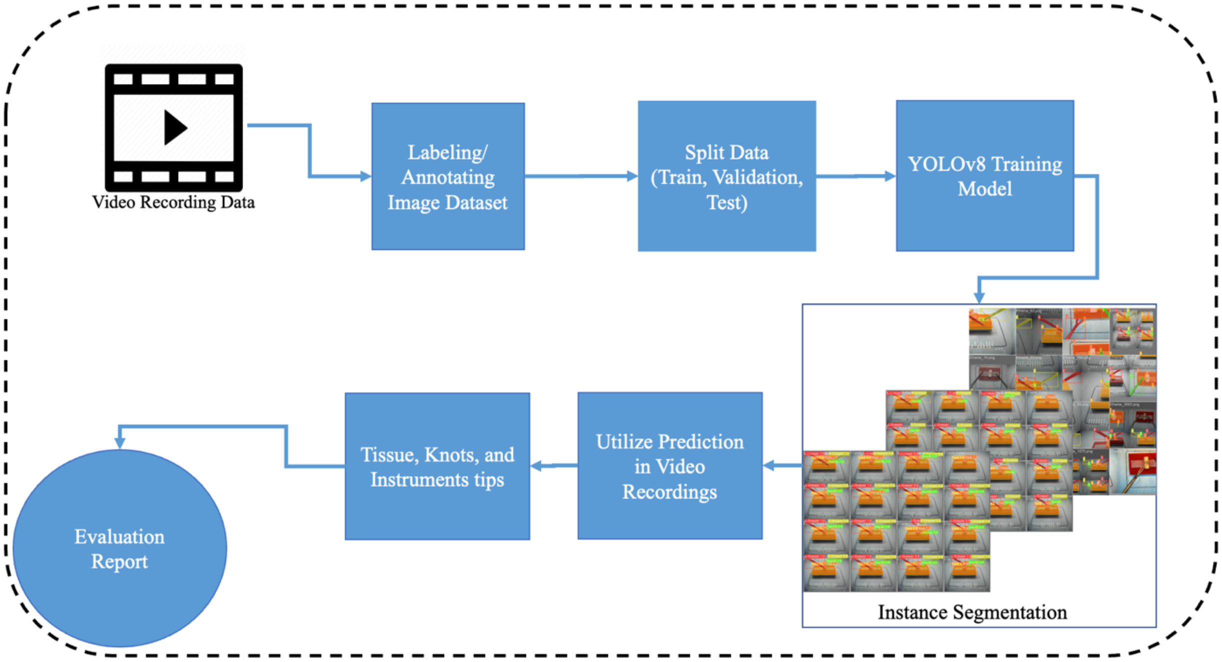
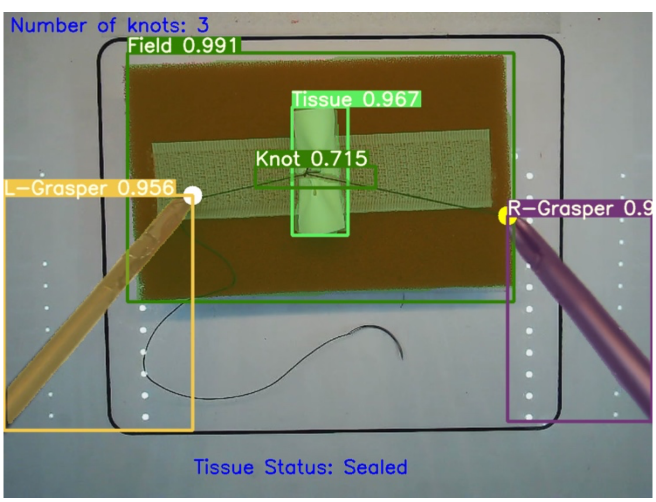


Figure 1. Process flowchart of the proposed work

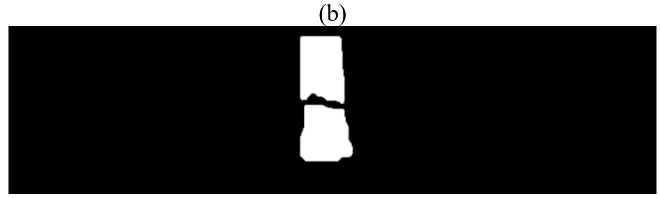
TABLE I. EVALUATION METRICS

CLASS ID	CLASS NAME	AVERAGE MASK PRECISION (AP)
0	L-GRASPER	99.00%
1	KNOT	99.00%
2	TISSUE	99.90%
3	FIELD	100.00%
4	R-GRASPER	98.90%
5	NEEDLE	97.20%
PRECISION: 0.991		**RECALL: 0.983**
MAP50: 0.992		**MAP50-95: 0.823**



(a)

(b)



(c)

Figure 2: (a) Shows the results of the tool's tip detection and the suturing task, (b and c) illustrate the knot and tissue mask detection when the tissue is sealed

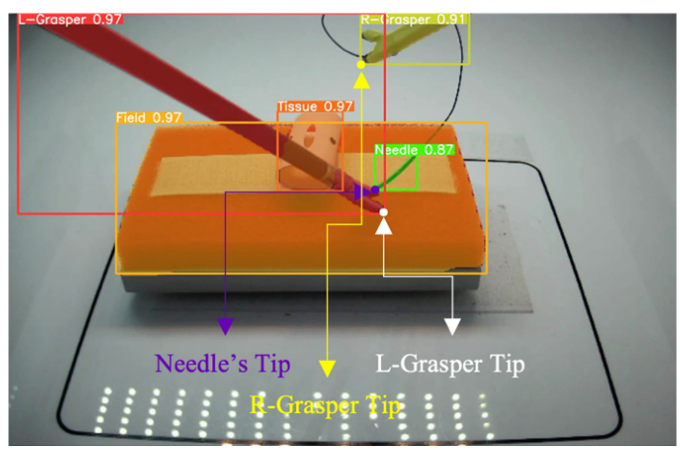


Figure 3. Illustration of the detection of the surgical instruments' tips