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Surgical Robotics For Cancer Treatment

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Abstract
Robotic technology is improving surgery by increasing dexterity, stability, and precision. Robots guide tools to the treatment location during image-guided surgeries using computed tomography and magnetic resonance imaging data. This calls for sensors to register the patient's anatomy with the preoperative picture data, as well as novel algorithms and user interfaces for surgery planning. Through the use of remotely operated robots, minimally invasive procedures enable the surgeon to operate inside the patient's body without creating significant incisions. Under these access restrictions, specialized mechanical designs and sensor technologies are required to maximize dexterity. Numerous surgical specializations can benefit from the use of robots. Robots guided by images can biopsy brain lesions during neurosurgery with little harm to surrounding tissue. Robots are frequently employed in orthopedic surgery to precisely shape the femur to fit replacement hip joints. Robotic systems are also under developed for closed-chest heart bypass, for microsurgical treatments in ophthalmology, and for surgical training and simulation. Despite the promising outcomes of the first clinical experience, concerns about safety, performance validation, high capital expenditures, and clinician acceptance still need to be addressed.
Keyword: *Robotic technology , Cancer, CycleGAN*

I INTRODUCTION

In recent years, the medical community has come to accept robot-assisted surgery more and more. In robot-assisted surgery, the treatments are carried out through tiny incisions and the surgeons are given sophisticated control and clever tools [1]. With the help of specialized tools and a laparoscope or endoscope, these surgical systems allow doctors to treat each patient individually, increasing patient safety [14][5]. Because the surgeon collaborates with robotic equipment, an intraoperative human-machine interface is required [2]. The intra-operative assistance system helps the pros during surgery and trains the aspiring surgeons [16]. These systems facilitate interaction with technological additions, help identify surgical actions during any operation, and offer support and guidance based on the surgical acts and situation [12]. To understand the surgeons' aim, the witnessed demonstration must be monitored and examined [17]. This can be accomplished by recording the instruments movements made by the surgeons during an intervention with a laparoscope or endoscope [11]. This is achieved by first detecting surgical tools in numerous portions (segmenting surgical instruments in each consecutive frame for a full surgical video) and then tracking specific places on the instrument as the procedure is being performed [4]. In order to enable monitoring or coding of the actions, multi-class segmentation of surgical tools is essential for allowing instrument detection with a classification between the portions [9]. The goal of this work is to create a segmentation technique that can separate numerous parts, such as linked sets of surgical instruments (such as the shaft and clasper), from any number of devices that are shown in the surgical film[3].
The treatment of rectal cancer has entered a new phase of sophisticated minimally invasive surgery thanks to robotic surgery[10]. Up to 1,037,000 procedures have been carried out in 67 countries since the first da Vinci Surgical System (Intuitive Surgical Inc., Sunnyvale, CA, USA) surgery was successfully completed in 2000 [15]. The da Vinci System, which comes in the following models: da Vinci Si, X, Xi, and SP, is now the most popular robotic surgical system in the world. Robotic surgery is a recently developed method that is thought to address the limitations of laparoscopic surgery and usher in a new era of minimally invasive surgery [6].

Three components currently make up the standard robotic surgery system: a video tower with system processors and a high-definition three-dimensional (3D) vision system; a surgeon console; and a patient-side cart with interactive robotic arms attached to the surgical tools [5]. Improved dexterity, greater range of motion at the tool tips, improved ergonomics, the removal of physiological tremors, and a steady camera with a three-dimensional vision are all clear benefits of robotic surgical systems [13]. Therefore, when compared to traditional laparoscopy, a robotic system offers more notable benefits for carrying out a higher-quality procedure in a small area (such the pelvic cavity) [7].

III PROPOSED METHODOLOGY

By defining viable C-space, this work explores the issue of taking tool shape and dexterity into account. A variety of techniques, such as potential functions or graph-search approaches, are then used to approach the path planning [8]. Potential functions have been used to indicate the existence of impediments (repellent potential) and goals (attractive potential) in safe path planning. It is anticipated that the tool will use the aggregate of these potentials to attain the goal without running into any roadblocks. There have also been additional methods developed that are based on the subdivision of the C-space. Path planning involves using a set of non-overlapping pavings to divide the C-space. Interval techniques have therefore been developed to improve computing efficiency. Although the path planning of irregularly shaped tools is addressed by the interval approach, the path planning of tools with variable shapes has not been addressed. Interval analysis using traditional techniques based on the C-space subdivision successfully establishes whether a particular box with intervals is inside or outside the feasible region. This method serves as the foundation for our work, in which we define the shape of surgical tools as interconnected intervals and create an algorithm that takes into account any tool's shape and dexterity.

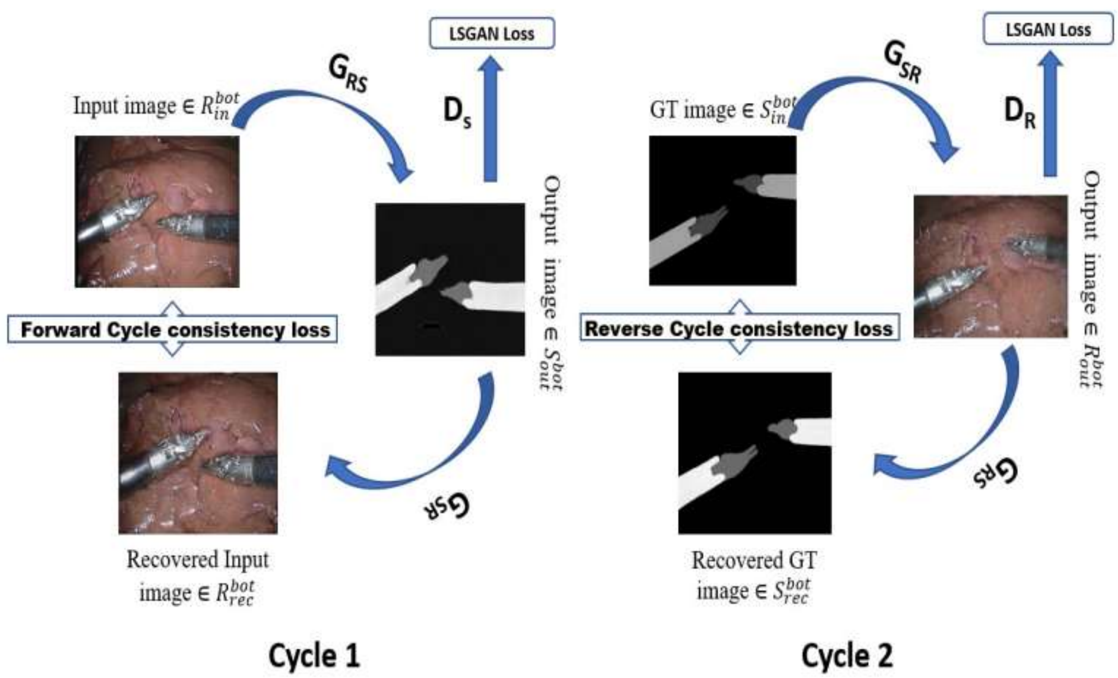

Figure 1: Unpaired training pipeline

Due to the complexity of surgical backdrops and the range of surgical instruments employed, training data in the field of robotic-assisted operations is few, while testing data is diverse. The suggested model is an improved iteration of CycleGAN, which was first used to the challenge of image-to-image style transfer. This model generates very accurate results for big unknown testing data using a modified generator network, even with minimal training data. The instrument shaft (class 1) and the clasper (class 2) must be separated from the surgical background (class 3) in order to perform multi-class segmentation, which is the focus of the proposed study. Our goal is to learn mapping in an unsupervised way that can be applied to images that haven't been seen before. Figure 1 shows the process for the training and testing phases. The developed CycleGAN's discriminators and generators networks are trained alternately during the training phase to increase each other's accuracy. Two distinct cycles of unpaired training are used to optimize the model's weights depending on the loss functions. During the testing phase, the intended generator network receives the testing dataset and uses it to generate the multi-class segmentation output of surgical equipment. Therefore, the most important part of the suggested methodology is the training pipeline, which is shown next.

3.1. Robotic instrument segmentation

As seen in Figure 3.3, the suggested network is trained for two distinct cycles. A synthetic version of the original raw surgical images, Rbotrec, is created in cycle 1 by the generator GRS using Rbot as input to create multi-class segmented output images, Sbot out, which are then fed back into the generator GSR. The discriminator DS determines if the image produced by generator GRS is authentic or fraudulent by comparing Sbot out with the ground truth images Sbot in. Likewise, generator GSR uses Sbot as input to produce the raw surgical images in cycle 2.

IV EXPERIMENTS

segmented surgical devices in the raw surgical movies and the corresponding ground truth (GT) videos. For training the suggested model, these are used to create the ground truth label pictures and raw input photos. To train the network, raw input frames and frames from the segmented instrument are retrieved. For the segmentation findings, we examined many GAN networks (InstruSegNet, U-Net based GAn, and ResNet based GAN); the unpaired training method is used to segment surgical equipment of multiple classes (both rigid and robotic). The input and ground truth images are obtained by extracting the image frames from the videos. Weighted image overlay, an image processing technique, is used to merge frames with left and right instruments for multi-instrument interventions. Forty 2D in-vivo photos from four colorectal procedures that were utilized for training are included in the stiff dataset. There are 160 2D photos with annotations total, and each pixel is labeled as either background, shaft, or manipulator. Ten more 2D photos for four recorded operations and two more recorded procedures with fifty 2D images are included in the test dataset.

Network	**Instrument**	**Mean IoU (%)**
Deep residual Network	Robotic	77.68
TernausNet-16	Robotic	65.5
Proposed Method	Robotic	98.89

Table 1: Comparison Results Based On Iou For Multi-Class Robotic instrument Segmentation

The comparative results between the suggested method and the state-of-the-art for multi-class segmentation of robotic instruments are displayed in Table 1 based on mean IoU. For multi-class robotic instrument segmentation, the highest mean IoU recorded in previous works is 77.68%. According to Table 1, the suggested method's highest mean IoU indicates a roughly 3% improvement in robotic instrument segmentation over the earlier approaches. The results clearly show that the suggested method produces good accuracy on a large and unknown test set of data while supporting viable training on a small amount of the dataset.

CONCLUSION

Robotic surgery has become a paradigm shift in the surgical treatment of gynecologic cancers, not just a technical development. With its compelling combination of accuracy, visibility, and ergonomic benefits that directly translate into better patient outcomes, its launch has ushered in an era of minimally invasive methods to difficult oncological operations.

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