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Automated cross-specialty surgical step recognition: a novel Multi Task Learning approach

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Introduction

Surgical training is a complex process in which apprenticeship remains the foundational element by which knowledge is transferred. Residents learn and fine-tune their surgical abilities by actively reviewing surgical procedures and later on by practicing under the supervision of a more experienced surgeon. Common actions (e.g., tissue dissection and suturing) are widely used across different surgical fields and procedures. For instance, learning the principles of dissection in an appendectomy will increase one's ability to perform the same action in other procedures.

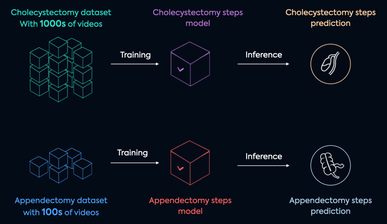
In this work, we use an analogy of these concepts in the computer vision domain and apply it to the foundational task of surgical step recognition. We apply an AI-based method, Multi Task Learning (MTL), which can automatically recognize the surgical workflow steps of multiple procedure types and scale across several surgical specialties.

Methods

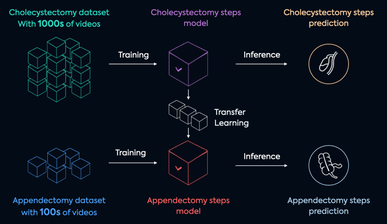
Most studies on automating surgical step recognition have focused on a single procedure type. Recent work has shown that transfer learning can be utilized to apply knowledge gained from one procedure to improve models' performance in other procedure types. However, scaling transfer learning to many procedures poses several challenges. First, as all downstream procedures learn from the same main procedure, knowledge sharing is limited. Second, this learning process requires optimizing each procedure's model separately.

MTL can scale efficiently beyond a single procedure or a single specialty and can simultaneously recognize the surgical steps of dozens of different procedures from four different specialties.

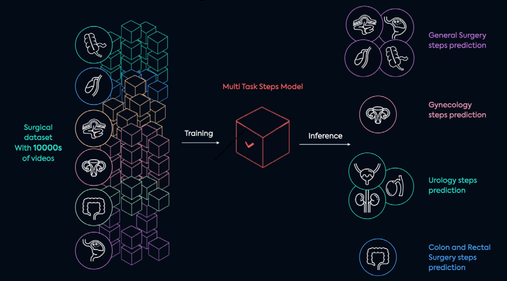
Single Procedure Learning



Transfer Learning (TL)



Multi Task Learning (MTL)



Data

7,768 surgical videos

25.5M seconds of surgical data

50+ different procedures types

4 surgical specialties

Results

On average, the MTL approach achieves 92% accuracy in detecting the correct surgical step on a diverse test set containing 1,934 videos, while transfer learning obtains 90% accuracy.

The benefit from the combined learning approach provided by MTL can be seen across all procedures evaluated, with a particularly significant gain in accuracy for specific procedures, e.g., Cardiac Sphincter Function +5.5% and TEP Hernia Repair +3.4%.

	Appendectomy	Cholecystectomy	Colectomies	Cardiac Sphincter Function	Gynecology	Nephrectomy	Sleeve Gastrectomy	TAPP Hernia Repair	TEP Hernia Repair	Radical Prostatectomy	Transurethral	Average
Transfer Learning	92.63	93.04	93.79	74.84	91.84	92.63	94.45	91.74	85.4	89.4	89.58	89.9
Multi Task Learning	94.12	94.17	94.45	80.33	93.98	93.44	96.19	93.25	88.79	92.11	91.02	92.0
MTL & TL Difference	↓ 1.49	↓ 1.13	↓ 0.66	↓ 5.49	↓ 2.14	↓ 0.81	↓ 1.74	↓ 1.51	↓ 3.39	↓ 2.71	↓ 1.44	↓ 2.1

Discussion

This work shows that MTL achieves better results in the step recognition task compared to transfer learning. It demonstrates a cross-specialty approach in which a single model learns to perform across four surgical specialties. Additionally, MTL enables Surgical Intelligence systems to operate at scale by simplifying the training and deployment processes.

In future works, we plan to explore how this approach can handle other tasks, such as surgical event detection and safety milestone recognition, with the aim to further automate surgical workflow analysis.

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