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EVALUATION OF ENDOSCOPE CONTROL ASSESSMENT SYSTEM

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ABSTRACT

Colonoscopy procedures are commonly performed to screen the colon for cancer-causing polyps. These procedures require highly trained practitioners and extensive training is necessary to perform proficiently. The Endoscopic Control Assessment System (ECAS) was developed to train and assess practitioners using a magnetic tracker and camera imaging. The magnetic tracker is used to track the tip motion of an endoscope during the insertion and retraction procedure of colonoscopy. In addition, camera imaging is used to track the angle of the control knobs during the procedure. The colon deflection of a manikin during a colonoscopy was successfully tracked to be averaged as 31, 54, and 10 mm for the three trials. Visual processing showed the control knob motion could be successfully tracked during a manikin colonoscopy procedure. The ECAS system was shown to be able to successfully measure user inputs during a manikin procedure.

Keywords: Colonoscopy, Endoscope, Medical Training,

1. INTRODUCTION

Colorectal cancer (CRC) has emerged as one of the most threatening malignancies worldwide [1]. Cases have been continuously growing over the past decade and are beginning to impact the younger population as well. The American Cancer Society provides updates of CRC occurrence based on incidence data. In 2020, it was determined that approximately 148,000 individuals were diagnosed with CRC and about 53,200 died from the disease, including 17,930 cases and 3,640 deaths in individuals aged younger than 50 years [2]. CRC morbidity and mortality can be mitigated through appropriate screening and surveillance.

Preventative screening is a critical first line of defense for growing incidence, as early detection can significantly improve outcomes for CRC. Colonoscopy remains the preferred method of preventative screening. It is a procedure that is one of the most expensive screening tests routinely performed. Millions of these procedures are performed each year in just the United States [2]. Because of this, procedural efficiency is highly impactful on the healthcare system. Despite this large demand for colonoscopy procedures and the importance of efficiency, there is only a 90% completion rate for physician competency, and there is a very high learning curve to achieve this target [3]. This completion is defined as obtaining cecal intubation, which is reaching the end of the colon when inserting an endoscope [4]. Failure of completion results in repeating the colonoscopy procedure, which is expensive and unfavorable, as the patient must prepare and go under anesthesia once again, a risky process. During this procedure, highly trained physicians must navigate the endoscope into position using complex controls and limited visualization. These difficult skills are generally learned by apprenticeship model training, where physicians practice performing these procedures with the guidance of experts [5]. One study evaluated that the performance of about 300 colonoscopy procedures is necessary to reach the clinical standard for a quality colonoscopy [4]. This is not efficient with the number of procedures that need to be performed annually, as the numerous procedures that are needed to become competent are expensive, time-consuming for both trainers and trainees, and potentially risky for patients [6].

To confront this issue, state-of-the-art training systems already exist and continue to be developed. These include manikin simulators and advanced high-cost robotic systems, both of which have their own merits.

Manikin simulators are widely used as they provide a flexible and airtight material to imitate a realistic colon which would allow practical colonoscope insertion and withdrawal training. Two of the most common examples of this are the Koken Colonoscopy Training Model (Koken Co. Ltd., Tokyo, Japan, $3800) and the Kyoto Kagaku Colonoscope Training Model (Kyoto Kagaku Co. Ltd., Kyoto, Japan, $2450). They train users to perform complex skills and techniques that are required to go through diverse cases of anatomy as they accurately stimulate the movement of an endoscope and the complex looping mechanics that occur. This makes them ideal for advanced skills training.

Advanced high-cost robotic systems are beneficial as they use virtual reality and robotics to stimulate the haptics and visualization of an endoscopic procedure while providing sensor-based feedback. These can include the Endoscopy Accutouch System (Immersion Medical; Gaithersburg, MD, $64,500) and the GI Mentor (3D Systems, Rock Hill, SC, $74,750). Multiple studies have shown that these devices are ideal for improving novice proficiency [4].

Although both training simulators are very valuable, there are various limitations that exist which can hinder their effectiveness. Manikins offer realism in the looping mechanics, but they don't offer guided feedback and assessment [7]. This forces the user to learn through the method of trial-and-error, which is very time-consuming, especially without the guidance of an expert. Additionally, while advanced high-cost robotic systems are effective in early training and offering guided feedback, they lack high levels of realism in complex looping and haptic mechanics [7]. This can hinder advanced learning since, as studies show, the optimal effectiveness will only be during early novice training and improvements do not extend to subsequent expert improvement. Accurate specific feedback has been shown to be critical in advancing the learning curve.

An Endoscopic Control Assessment System (ECAS) that utilizes video and magnetic tracking was developed. This new training system combines the concepts of previous systems as it allows the use of a manikin with advanced feedback and assessment. It includes a magnetic tracker at the endoscope tip to measure tip movement as the user goes through the path of a colon. A camera system is also included to capture video and accurately quantify user inputs at the endoscope control knobs. This training system analyzes the physician's control inputs into an endoscope and provides guided feedback by measuring control knob and tip motion. The ECAS was introduced by Ferri et al. [5], and the accuracy was measured through controlled laboratory experimentation outside of the manikin. This paper examines the ECAS system's ability to capture steered position and knob motion during an endoscopy procedure performed by a medical expert on a manikin

2. MATERIALS AND METHODS

Colonoscopy procedures were performed on the *Kyoto Kagaku Colonoscope Training Model* (Kyoto Kagaku Co. Ltd., Kyoto, Japan) manikin by a trained expert with a sensorized endoscope, as shown in Figure 1. The control knob and tip motion were measured during the colonoscopy procedure. The endoscope is sensorized with a magnetic tracker and a camera mount system, as shown in Figure 1.

The magnetic tracker used on the distal tip of the endoscope is a Northern Digital Inc. (Waterloo, ON) 3D Guidance TrakSTAR Model 90 electromagnetic probe. This magnetic tracker is set through the instrument port of the endoscope to the tip; capturing tip position information as it goes through a manikin of a colon. The magnetic tracker collects data at a rate of 180 Hertz. The motion of fiducial marked knobs is recorded by a camera attached onto the camera mount. The camera used is an Arducam 1080P Low Light Low Distortion USB Camera Module. This camera allows the production of clear imaging of the control knobs without interfering with user control. The feasibility of both systems was assessed through the analysis of the path of the magnetic tracker through a colon manikin and video processing of the control knobs.

A medical expert conducted three trials of an endoscopic procedure on the manikin. Position of the endoscope tip and positions of the control knobs were measured during this entire procedure. MATLAB by MathWorks (Natick, Massachusetts) was used to perform the position and video analysis.

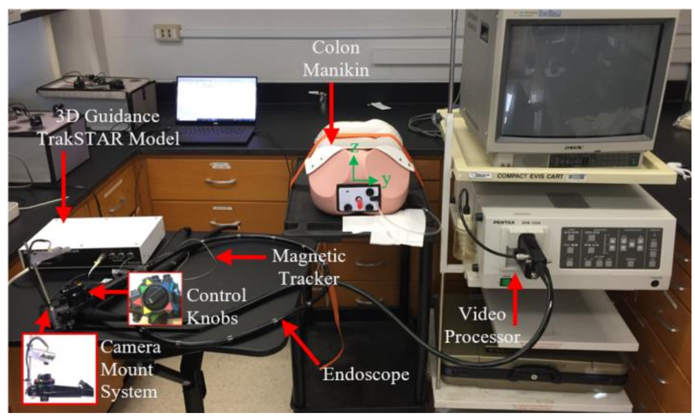

FIGURE 1: SETUP OF ECAS FOR THE ENDOSCOPIC DATA COLLECTION IN HERSHEY MEDICAL CENTER

3. RESULTS AND DISCUSSION

The system was able to successfully track the movement of the endoscope during the entire manikin procedure for each of the trials, one example trial is shown in Figure 2. The system was able to measure this at the sensor accuracy, 1.4 mm RMS. Each data point is given a specific quality value (value output from magnetic tracker). Data with quality values below an acceptable threshold were removed to ensure high position accuracy.

Colon deflection was measured by comparing the retraction path to the insertion path as shown in Table 1 and Figure 3. Retraction creates minimal colon deflection compared to insertion and therefore by comparing the differences in these values the deflection can be measured. Deflection is a significant value to measure as too much colon deflection implies there was a large amount of force applied to the colon. Large forces on the colon wall can cause tissue damage and in extreme cases perforation. Measured deflection was found to vary between the 3 trials with the highest deflections measured in test 2 of 212 mm with an average of 54 mm, as shown in Table 1, and the lowest deflections measured in test 3, with a maximum deflection of 60 mm and an average of 10 mm. This demonstrates that deflection can be significant and accurately measured with the ECAS system.

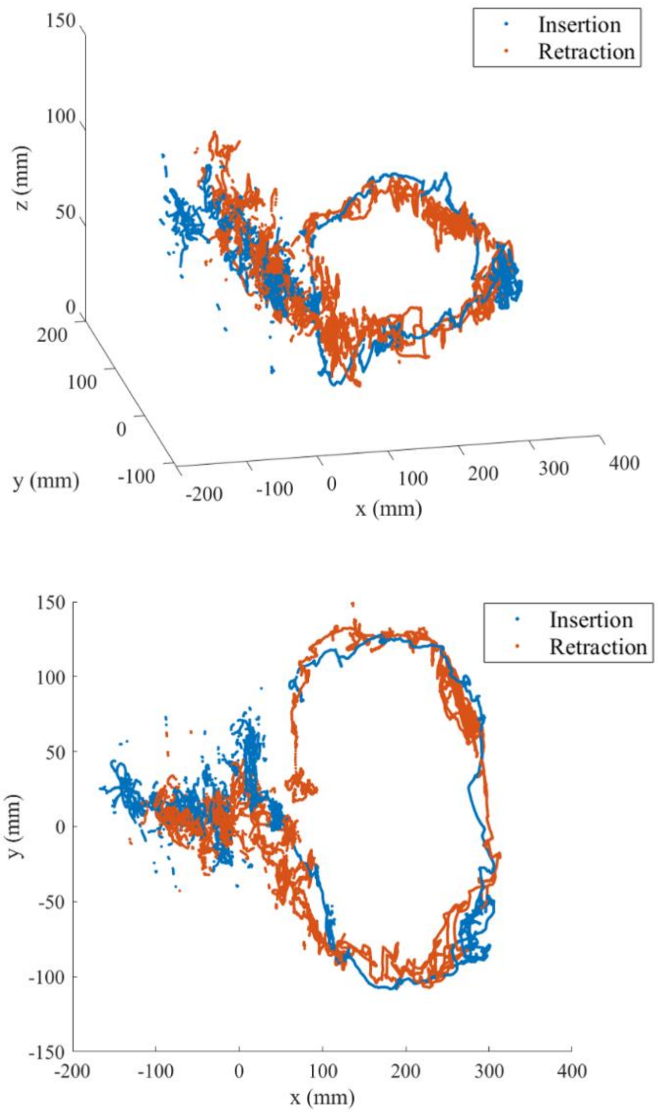

FIGURE 2: THREE-DIMENSIONAL PLOT OF PATH TRACKED BY MAGNETIC TRACKER IN COLON MANIKIN (TOP). TWO-DIMENSIONAL PLOT OF PATH TRACKED BY MAGNETIC TRACKER IN COLON MANIKIN (BOTTOM).

TABLE 1: MAXIMUM AND AVERAGE PATH DEFLECTIONS OF THE THREE CONDUCTED TRIALS.

	Maximum Deflection (mm)	Average Deflection (mm)
Trial 1	196	31
Trial 2	212	54
Trial 3	60	10

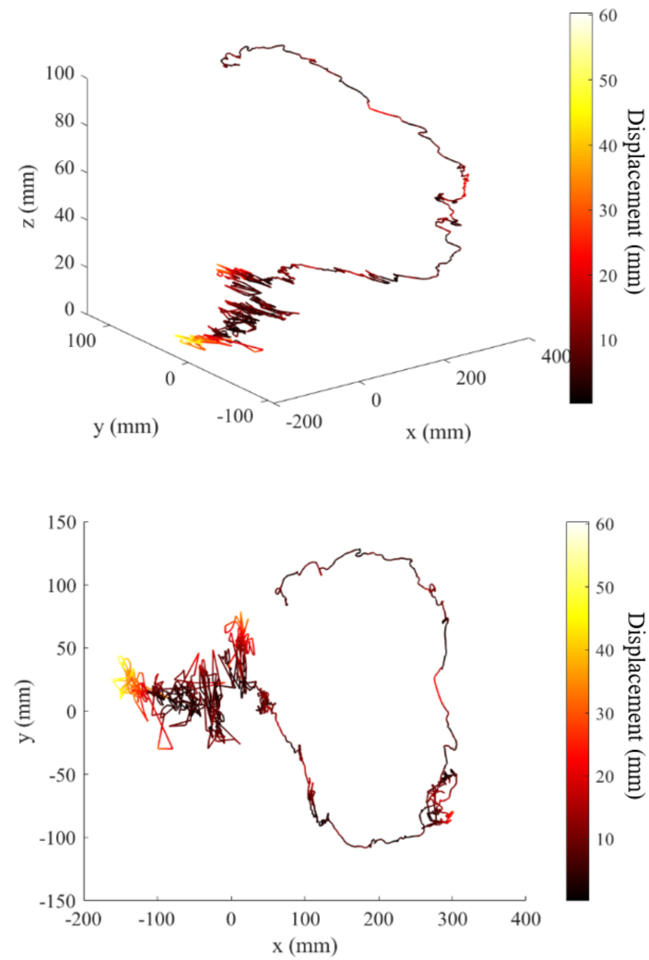

FIGURE 3: PATH DEFLECTION COLOR MAP BETWEEN INSERTION AND RETRACTION IN XYZ PLOT (TOP) AND XY PLOT (BOTTOM).

The control knob position was determined by performing video analysis using MATLAB by MathWorks (Natick, Massachusetts). Colored fiducials on the knobs, as shown in Figure 4 were tracked and then angle was determined. The robust software was written to account for fiducials being periodically covered by the user's hand during movement.

FIGURE 4: CONTROL KNOB WITH YELLOW MARKER COVERED FOR TEST TRIAL.

Figure 5 displays the turning angle from the up/down control knob over 25 seconds of a manikin insertion. As shown this movement varied by 120 degrees and had several areas of distinct motion where the user made large adjustments in the control knob position. The visual analysis was able to process information from 99% of the recorded frames. 1% of the frames due to shadows and/or knobs being completely covered did not have positional data that could be automatically extracted.

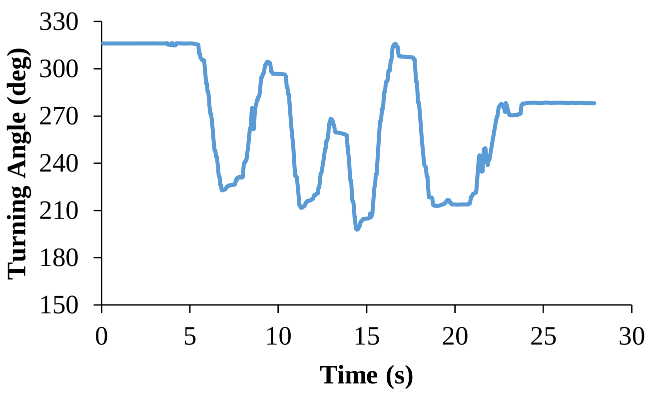

FIGURE 5: TURNING ANGLE OF CONTROL KNOB OVER TIME OF TEST TRIAL WITH HIDDEN MARKER.

4. CONCLUSION

ECAS ability to measure endoscope tip and control knob movement was evaluated on a manikin. Three trials were conducted on inserting and retracting an endoscope from a manikin by a medical expert at Hershey Medical Center. The endoscope tip was able to be tracked through its full range of motion with high accuracy. Video processing measured the user movements of the control knobs.

Future work will incorporate ECAS into colonoscopy manikin training with the use of a graphical user interface to provide automated performance feedback to users. This will allow users to analyze and understand their performance and how to further advance their skills.

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