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Image-Based Pose Estimation of an Endoscopic Instrument

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Abstract— **This video shows a system that estimates the pose of a flexible endoscopic instrument, based on the endoscopic images. A three-dimensional rendering of the instrument is matched to the actual instrument that is observed through the endoscopic camera. This system was evaluated in an anatomical model of a colon. The estimated position of the tip of the instrument was compared to measurements performed with an electromagnetic tracker. The errors of the position estimation were 2 mm, 2.2 mm and 1.7 mm in the horizontal (x), vertical (y) and away-from-camera (z) directions, respectively.**

I. Introduction

Flexible endoscopy is a minimally invasive procedure, which allows the physician to examine the internal body cavities using a flexible endoscope. The physician uses the wheels on the control handle to control the movement of the tip which contains the camera.

Recently, advanced endoscopes have been developed that not only allow the physician to examine the patient, but also enable performing interventions, such as removing malignant tissue. The endoscope is equipped with multiple instruments, that have multiple degrees of freedom (Fig. 1).

Marescaux and his colleagues have used the Karl Stortz Anubis endoscope to perform interventions [1]. Unfortunately, multiple physicians are required to control the endoscope and the instruments. This is undesirable, because optimal cooperation is required, which is difficult. Furthermore, this is very costly.

A solution to this problem would be to build a teleoperated system, in which a single physician can control the endoscope and all instruments from a single surgical console. This would allow intuitive control of the entire intervention.

Thus, the goal is to actuate the endoscopic instrument so as to follow the movements of the input device which is operated by the physician. However, actuating the instruments is not straight-forward, since there is a lot of friction and compliance between the instrument and its actuation point. This causes hysteresis, which prohibits convenient steering. In order to reduce this effect, a feedback loop can be used to control the position of the instrument based on the input given by the physician.

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Fig. 1. The Karl Storz Anubis endoscope features two instruments with multiple degrees of freedom. This enables performing complex interventions. However, manual control of the instruments is difficult.

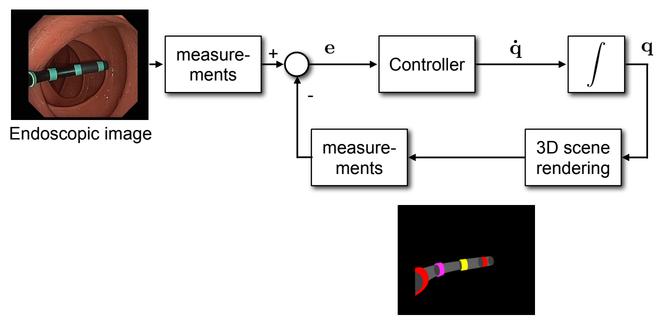

Fig. 2. The estimator is a visual servoing control loop, which matches a 3D rendering of the instrument to the instrument that is observed in the endoscopic image.

II. Pose Estimation

Such a feedback loop requires information on the current position of the instrument. We have developed a pose estimation algorithm that enables reconstruction of the instrument pose based solely on the endoscopic images, without adding sensors to the endoscope system [2]. In this video, we will discuss this pose estimation algorithm.

In order to enable accurate the tracking of the instrument, we have placed four markers on it. We use a visual servoing inspired approach to match a three-dimensional rendering of the instrument to the actual observed instrument. This approach is shown in Fig. 2. The state of the estimator, denoted $\mathbf{q}$, describes the insertion, rotation, and bending degrees of freedom if the instrument. Using the current state $\mathbf{q}$, a three-dimensional rendering of the instrument is created. From this rendering, the centroids of the markers are measured. These are compared to the centroids of the markers in the endoscopic image, resulting in an error $\mathbf{e}$. The controller computes the required state change $\dot{\mathbf{q}}$ using the pseudo-inverse of the interaction matrix, which describes the relation between the change of the state $\dot{\mathbf{q}}$ and the change of the error $\dot{\mathbf{e}}$.

III. Evaluation

The system was evaluated in an anatomical model of a colon. The estimated position was compared with a position measurement from an electromagnetic tracking system. The root-mean-square (RMS) errors of the position estimation were 2.3 mm, 2.2 mm and 1.7 mm in the horizontal (x), vertical (y) and away-from-camera (z) directions, respectively.

References

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