Analysis of the Impact of Intestinal Motility on the Speed Estimation of Video Capsule Endoscope

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Abstract — **This paper analyzes the impact of the intestinal motility on the speed estimation of the video capsule endoscope. By applying two speed estimation algorithms on two kinds of intestine models respectively and comparing the empirical results in these four scenarios, we have revealed the influence of the intestinal motility on the speed estimation.**

I. Introduction

There has been a trend in using the video source of the capsule endoscopy to estimate the speed of the capsule in order to locate it in the small intestine [1]. Knowing the exact size, which is the diameter, of the small intestine is extremely important since the speed estimation algorithms completely rely on it. In practice, most researchers assume a constant diameter to simplify the scenario.

In this paper, we analyze the impact of the intestinal motility on the speed estimation of the video capsule endoscope (VCE). To this end, we create a virtual testbed and emulate of the intestinal motility and the procedure of VCE. After that, we introduce two speed estimation algorithms respectively for two scenarios. One is for an intestine with a constant diameter (uncontracted); the other is for a contracted intestine with a changing diameter. Based on the experiment results, we come up with a suggestion on how to choose these two algorithms according to different situations. Our results and conclusion can be referred by other researchers in order to increase the robustness of the speed estimation algorithms.

II. Testbed Setup

Figure 1 shows the exterior and interior appearances of the virtual small intestine model. It is a cylindrical tube with a twisted shape. A piece of porcine intestine texture is used to simulate the surface of the small intestine. A virtual camera is set traveling along the model, providing emulated pictures every a certain step. A Phong light source is also attached on the camera to simulate the illumination effect.

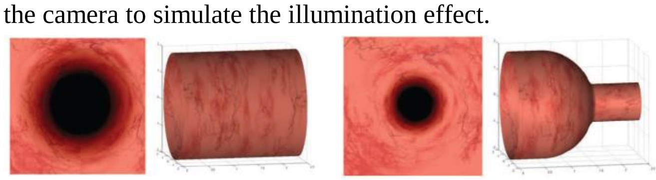

Figure 1. Emulation of the uncontracted and contracted small intestine.

III. Experiment on Speed Estimation

In our previous work [1] [2], we have discussed two speed estimation algorithms respectively for small intestine with and without intestinal motility, as shown in Figure 2. The project ion of each feature point [1] P on the screen moves from P_1 to P_2. Using inverse projection and trigonometric functions can calculate the speed of the capsule based on the motion of the projections of the feature points as shown in (1) and (2).

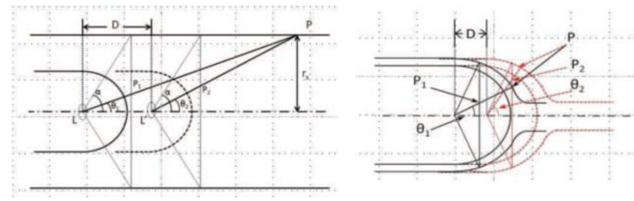

Figure 2. Speed estimation on the uncontracted and contracted intestine.

$$D = \frac{r_s}{\tan\theta_1}\left(1 - \frac{\tan\theta_1}{\tan\theta_2}\right) \quad (1) \qquad D = r_s(\theta_2 - \theta_1) \quad (2)$$

The speed of the capsule in uncontracted and contracted intestine can be calculated based on (1) and (2) respectively. To discover the impact of intestinal motility on the speed estimation, the two formulae are both applied to contracted and uncontracted intestine, forming four scenarios. The estimation result of each scenario is shown in Figure 3. The horizontal axes denote the angle formed by the feature point, lens and the central axis of the capsule (which is ϑ in figure 2).

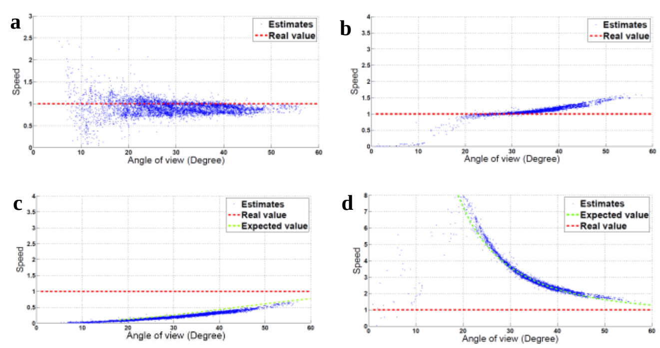

Figure 3. Speed estimation results. a is the result from (1) in uncontracted intestine; b is that from (2) in contracted intestine; c is that from (1) in contracted intestine; d is that from (2) in uncontracted intestine.

IV. Conclusion

This paper reveals the impact of intestinal motility on the speed estimation of the VCE. Based on the results, it is safe to say that given a known scenario (a, b), the estimates in the middle part (which is 20 – 40^{o} in our scenarios) are more trustable; also given an unknown scenario (c, d), the estimates in the outer part (> 50^{o}) are more trustable.

References

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[2] L. MI, G. Bao, and K. Pahlavan. "Design and validation of a virtual environment for experimentation inside the small intestine", In Proceedings of the 8th International Conference on Body Area Networks, pp. 35- 40, Boston, Massachusetts.

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