show poster

Poster Presentation
Capsule endoscopy
Monday, September 27, 2004, 12.15-14.00

Abstract: MON-E-17

Citation: Endoscopy 2004; 36 (Suppl I) A76

COMPUTERIZED IMAGE ANALYSIS OF WIRELESS CAPSULE ENDOSCOPY VIDEOS USING A DEDICATED WEB-LIKE MODEL OF DEFORMABLE RINGS - A FEASIBILITY STUDY

P.M. Szczypinski[1], P.V.J. Sriram[2], R.D. Sriram[1], D. Reddy[2]

[1] *Manufacturing Systems Integration Division, National Institute of Standards and Technology, Gaithersburg, United States*

[2] *Asian Institute of Gastroenterology, Hyderabad, India*

INTRODUCTION: Wireless capsule endoscopy (WCE) video recording consists of about 60,000 images captured at 2 frames per second, which are interpreted by an experienced endoscopist regarding the surface abnormalities like erosions, ulcers, bleeding, strictures etc. The process of video inspection is usually a tedious task that takes several hours.
AIMS & METHODS: The aim of the study is to develop and evaluate software for aiding WCE video analysis, such as coarse localization of the large-scale abnormal areas and areas of retention of capsule that require a detailed examination. A dedicated web-like model of deformable rings (MDR) was applied for pre-analysis of WCE video of gastrointestinal tract. The model determines relative movement of tube-like surface by comparing consecutive video frames with regard to displacement of its distinctive portions. During analysis, MDR creates a two-dimensional graphic representation or map of the gastrointestinal tract and computes an estimate of capsule velocity. This map serves as a quick reference to video sequences, supports rough identification of segments of the bowel, and provides data sufficient for localization of the large-scale abnormalities.
RESULTS: Ten known WCE recordings were included consisting of five normal and five abnormal cases (one case each of gross bleeding, multiple large erosions, ileal ulcers due to Crohn's disease, gastroparesis and ileal stricture). Using the maps and the corresponding video recordings certain characteristics have been recognized that indicate areas of bleeding, ulceration, obscuring luminal contents or froth, areas of capsule retention etc. Keeping these characteristics in mind, the maps can be glanced through for quick identification of abnormal areas for further detailed endoscopic viewing to ascertain the nature of these abnormalities. This method noticeably reduced examination time with 4 of the 5 abnormal recordings.
CONCLUSION: Computerized analysis of the WCE recordings is feasible and reduces the human labor involved in the interpretation of WCE images. Although the results of the present study are encouraging, the methodology needs to be tested using more data before clinical utility can be established.

COMPUTERIZED IMAGE ANALYSIS OF WIRELESS CAPSULE ENDOSCOPY VIDEOS USING A DEDICATED WEB-LIKE MODEL OF DEFORMABLE RINGS - A FEASIBILITY STUDY

Piotr M. Szczypinski[1, 2], Parupudi V. J. Sriram[3], Ram D. Sriram[1], D. Nageshwar Reddy[3]

[1]*National Institute of Standards and Technology, Gaithersburg, USA*
[2]*Institute of Electronics, Technical University of Łódź, Łódź, Poland*
[3]*Asian Institute of Gastroenterology, Hyderabad, India*

ABSTRACT

Aim: This study aims to develop and test software for aiding wireless capsule endoscopy (WCE) video analysis, such as the coarse localization of large-scale abnormal areas and capsule retention areas that require a detailed examination.

Method: Typical WCE video recording consists of about 60000 images captured at two frames per second. Such a recording is interpreted by an expert gastroenterologist, who identifies various mucosal abnormalities such as erosions, ulcers, bleeding, strictures etc. A dedicated web-like model of deformable rings (MDR) was applied for pre-analysis of WCE video of gastrointestinal tract to aid with the interpretation procedure. The model determines relative movement of tube-like surface by comparing consecutive video frames with regard to displacement of its distinctive portions. During analysis, MDR creates a two-dimensional graphic representation or a map of the gastrointestinal tract and computes an estimate of the capsule velocity. This map serves as a quick reference to video sequences, supports rough identification of segments of the bowel, and provides data sufficient for localization of large-scale abnormalities.

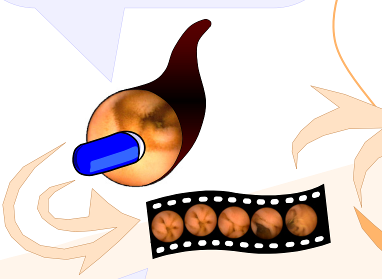
Results: Ten known WCE recordings consisting of five normal and five abnormal cases – one case each of gross bleeding, multiple large erosions, ileal ulcers due to Crohn's disease, gastroparesis and ileal stricture – were used as test cases. The produced maps clearly identified areas of bleeding, ulceration, obscuring luminal contents or froth, areas of capsule retention, etc.. A physician can quickly scan these maps and identify abnormal areas for further detailed endoscopic viewing to ascertain the nature of these abnormalities. This method noticeably reduced examination time with 4 of the 5 abnormal recordings.

Conclusions: Computerized analysis of the WCE recordings is feasible and reduces the human labor involved in the interpretation of WCE images. Although the results of the present study are encouraging, the methodology needs to be tested using more data before clinical utility can be established.

1 INTRODUCTION

The human small intestine cannot be visualized using a traditional endoscopic approach. The wireless capsule endoscopy (WCE)[6, 9] is a relatively new technique that facilitates the imaging of the small intestine. The WCE system consists of a pill-shaped capsule with built-in video camera, light-emitting diodes, video signal transmitter, and battery, as well as a video signal receiver-recorder device. The capsule is ingested and passes through the gastrointestinal (GI) tract. The transmitted images are received and recorded by an external receiver-recorder device.

The investigation of video recordings is performed by a trained clinician. The video interpretation involves viewing the video and searching for bleedings, erosions, ulcers, polyps and narrow sections of the bowel due to disease, or any other abnormal-looking entities. It is a tedious process that takes considerable amount of time, usually more than an hour per recording. The interpretation requires a high level of concentration while viewing, so as not to miss focal lesions that might be present in only few frames and could be easily missed. Froth or partially digested luminal content that obscures the mucosal details creates interpretation problems. Additionally, localization of the capsule is difficult and often inaccurate since neither the progression of the capsule nor the distance from a visual reference point can be estimated with reasonable accuracy.



2 VIDEO PROPERTIES

The wireless capsule endoscope used in this study produces color images at a rate of two frames per second for approximately 8 hours. The images cover a circular 140° field of view of the internal lumen of the GI tract. Since the shape of the capsule is elongated and the GI tract is akin to a collapsed tube, most of the time the wireless capsule endoscope aligns in a direction parallel to the GI tract, heading the camera lenses forward or backward. Therefore, it was assumed that most of the video frames contain images of the GI tract walls, which converge in perspective at the point located near the center of an image. As the capsule passes through, portions of the tract shift outward or toward the center of an image.

Folded walls of digestive tract or intense peristaltic movements may cause the capsule to change its pitch or yaw in relation to the axis of the GI tract. However, such changes do not last long and the capsule eventually repositions to stay parallel with the axis of the GI tract.

3 MDR MATCHING

In the current approach we follow relative movements[2-4, 8] of digestive system walls by matching of consecutive video frames using the model of deformable rings (MDR). The MDR is a mesh positioned in the plane of a video frame. It forms concentric rings surrounding the center of the frame.

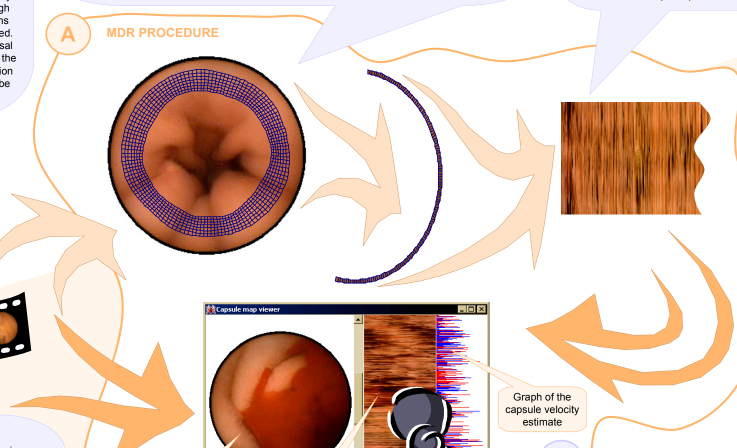
MDR nodes store information on local image properties that were found at their locations within a preceding video frame. The nodes search the vicinity of the current frame for locations having similar properties. Each node is pushed toward such a location. On the other hand, the arrangement of nodes within the MDR mesh has to be retained. This requirement is satisfied by modeling tensions[1, 5, 7] within the model structure. The elastic matching is a process of successive displacements of nodes intended for finding a state, in which a balance between the two effects is obtained.

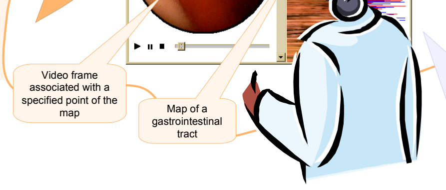
The process of elastic matching is repeated for every frame of the WCE video recording. It must be noted that as the capsule moves forward the MDR expands while matching consecutive video frames. If the capsule moves backward the model shrinks.

4 MAP ASSEMBLING

The average size of the MDR is computed after completion of every matching. If it is larger then some presumed maximum size, the outer ring of the model is erased and a new inner ring is created. If the model is smaller then some minimum size then the inner ring is erased and a new outer one is added. In either case of rings swapping, RGB vectors sampled at locations of nodes forming the outer ring are arranged in a row of pixels. All such rows are collected during the video processing to form an image or a map of a GI system surface. Furthermore, based on number of frames between swapping events, capsule pace is evaluated.

A MDR PROCEDURE





5 MDR UTILITY

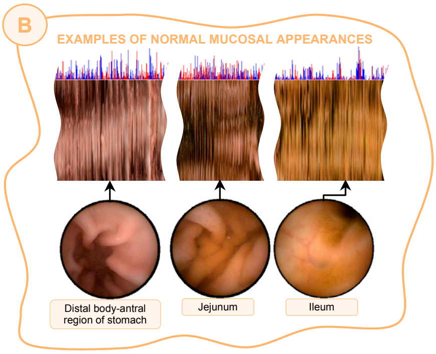
An ideal WCE preprocessed data should enable the clinician to quickly get an overview of the entire recording in terms of completeness of the procedure (whether the capsule endoscope traversed the entire GI tract) and adequacy of the procedure in terms of the recording quality (absence of obscuring froth or luminal content including gross bleeding). It should facilitate the identification of abnormal areas and quickly focus the efforts in interpreting the mucosal details of the selected areas rather, than scan the entire recording.

It was found that certain characteristics that indicate areas of bleeding, ulceration and obscuring froth could be recognized within maps. Therefore, the map can be glanced through for quick identification of such abnormal areas designated for further detailed investigation. Moreover, by means of capsule velocity estimate, areas of capsule retention (e.g. due to structural abnormalities like strictures or functional abnormalities like achalasia, gastroparesis, dysmotility or ileus) can be detected. The map can also serve as a reference to the WCE video recording.

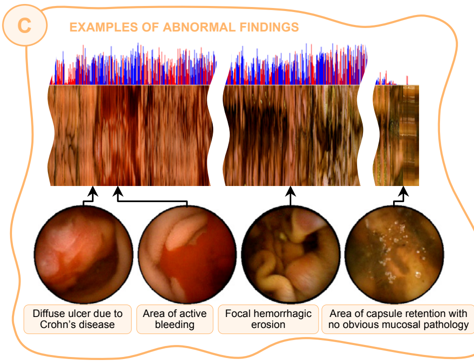
6 MDR IMPLEMENTATION

The MDR was implemented in C++ in DirectShow technology[10] as a video-processing module (filter). It was experimentally established that acceptable results could be obtained with models having 7 rings, with 128 nodes per ring. The matching process is performed in several phases with different coefficients of image influence and elasticity. The average time of processing the 8-hour video recording is less then 30 minutes using a PC with an Intel Pentium IV 1.8 GHz processor.

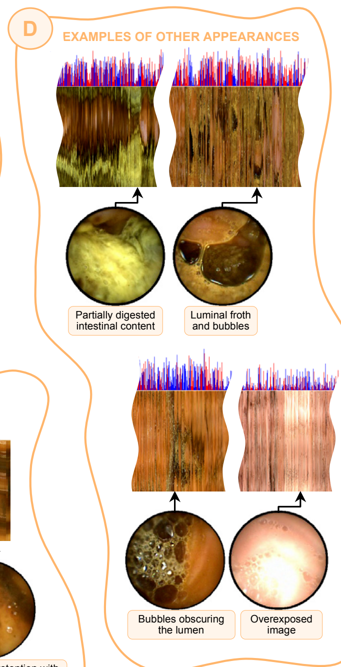
B EXAMPLES OF NORMAL MUCOSAL APPEARANCES



C EXAMPLES OF ABNORMAL FINDINGS



D EXAMPLES OF OTHER APPEARANCES



REFERENCES

1. M. Kass, A. Witkin, D. Terzopoulos, *Snakes: Active Contour Models*, Int. J. of Computer Vision, vol. 1, no. 4, 1988, pp. 321-331
2. H. Delingette, *Adaptive and deformable models based on simplex meshes*, IEEE Workshop on Motion of Non-Rigid and Articulated Objects, 1994, pp.152-157
3. Yao Wang, O. Lee, A. Vetro, *Use of two-dimensional deformable mesh structures for video coding*, IEEE Transactions on Circuits and Systems for Video Technology, Vol. 6, Dec. 1996, pp. 636-659
4. P. van Beek, A. M. Tekalp, N. Zhuang, I. Celasun, Minghui Xia, *Hierarchical 2-D mesh representation, tracking, and compression for object-based video*, IEEE Transactions on Circuits and Systems for Video Technology, Vol. 9, March 1999, pp. 353-369
5. P. Szczypiński, A. Materka, *Variable-Flexibility Elastic Model for Digital Image Analysis*, Bulletin of the Polish Academy of Sciences, Technical Sciences, Vol.47, No.3, 1999, pp. 263-269
6. G. Iddan, G. Meron, A. Glukhowsky, P. Swain, *Wireless Capsule Endoscopy*, Nature 2000, pp. 405-417
7. P. Szczypiński, A. Materka, *Object Tracking and Recognition Using Deformable Grid with Geometrical Templates*, ICSES 2000, pp.169-174
8. W. Badaway, *A structured versus unstructured 2D hierarchical mesh for video object motion tracking*, Canadian Conference on Electrical and Computer Engineering, Vol. 2, May 2001, pp. 953-956
9. D. G. Adler, C. J. Gostout, *Wireless Capsule Endoscopy*, Hospital Physician, May 2003, pp.16-22
10. Microsoft Corporation, *DirectShow*, http://msdn.microsoft.com/library