ISSN (Online) 2394-6849

International Journal of Engineering Research in Electronics and Communication Engineering (IJERECE)
Vol 6, Issue 5, May 2019

Wireless Capsule Endoscopy

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Abstract: **Wireless Capsule endoscopy (WCE) has been developed to allow direct view of the entire small bowel in human body in a non -invasive manner for the first time. But the visual inspection of a large number of video frames produced in each examination poses a tedious task to physicians. In this paper, we propose a novel scheme aiming for reduction of the number of frames in a video so as to partially solve this problem. To achieve this goal, the original WCE video is first divided into different segments by detecting video boundary among the video sequence. Key frames from different segments are then extracted to summarize the video with k-means clustering. Preliminary experiments on our present video data verify that it is promising to employ the proposed scheme to abstract a WCE video.**

Key words: WCE, video frames, clustering, novel scheme, medical .

I. INTRODUCTION

With the introduction of the flexible fibre optic endoscope in 1950s visualization of the oesophagus, stomach, upper small bowel and colon became possible. The flexible shaft of the instrument carried the fibre optic light bundles, power and the optical elements. It also contained cables, which allowed for control over the direction of the instrument. Therefore, the instrument was of relatively large diameter, making gastroscopy, small bowel endoscopy and colonoscopy [6] an uncomfortable procedure requiring sedation. Recent advances in development of low power complementary metal-oxide silicon (CMOS) imagers, mixed signal application specific integrated circuit (ASICs) and white light emitting diodes (LEDs) made possible development of a new type of endoscope – the swallowable video capsule. We describe the development of a video-telemetry capsule endoscope that is small enough to swallow (11×26 mm) and has no external wires, fibre optic bundles or cables. Extensive clinical and healthy volunteer trials have proved the effectiveness of the wireless endoscope in detection of pathologies in the GI tract.

The Wireless Capsule Endoscope (WCE), a small capsule-shaped device(fig 1) containing a video camera, LED lights, a power source and a wireless transmitter , is used to detect various diseases within the digestive system (e.g. in duodenum, jejunum, ileum, etc.). There are many different types of wireless capsule endoscopes and they are mostly developed and manufactured by Olympus, Intro medic etc.

Fig 1: capsule shaped device

Purpose:
– Aims to report on a new trend of research and development in the wireless capsule endoscope.

Design/methodology/approach:
– Presents a conceptual design of a wireless capsule endoscope having new features like navigation control, self-propulsion, higher rate image transmission, acquisition of samples, application of medications and so forth.

Practical implications:
– If successful, it will provide another way of least invasive medical treatment that must reduce pain of patients drastically.
The discomfort of internal gastrointestinal examination may soon be a thing of the past.

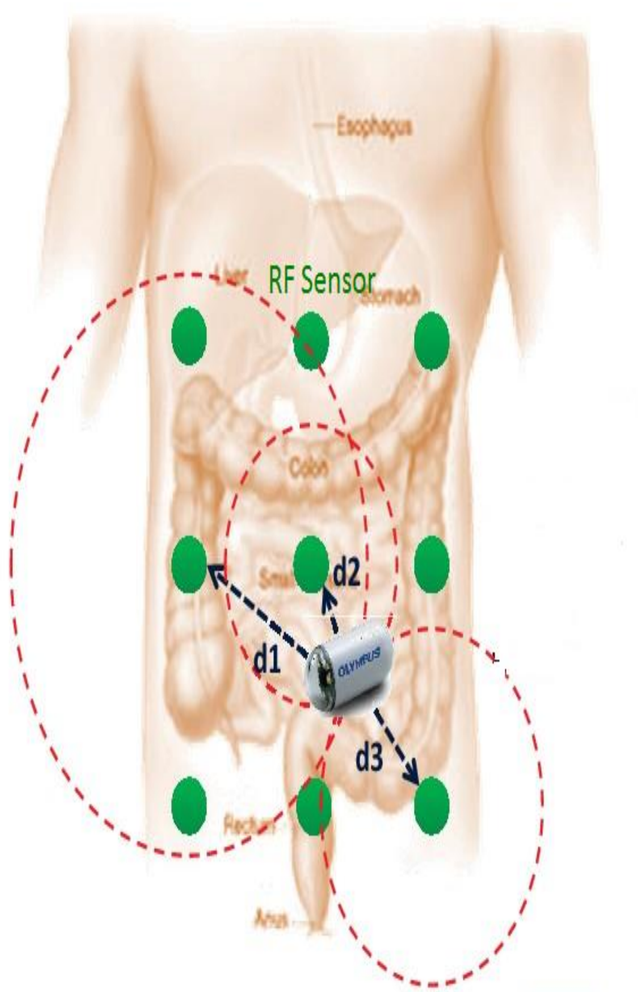

Fig 2: Olympus

OVERVIEW:
Wired endoscopy provides a practical technology for physicians to view the GI tract. However, limited by physical reasons, these traditional invasive endoscopies cannot be pushed through the entire GI tract, leaving the small intestine as a dead zone. They are inconvenient and cause intense pain. Further, they can increase the risk of intestine perforation and the cross contamination. The technological breakthroughs, including semiconductors, integrated circuits, illumination, and the greater understanding of human physiology, made possible development of a new type of endoscopy—wireless capsule endoscopy (WCE)[3]. A typical WCE system contains four parts: capsule endoscope (CE), receiving box, image working station, and software application. The CE is an electronic microsystem, which can be ingested to image the GI tract and transmit the images outside of the patient body.
The CE of the system is 11mm in diameter and 26mm in length, which is small enough to be swallowed by the patient. The CE is composed of 7 main models (fig 3) including optical dome, short-focus lens, CMOS (complementary metal oxide semiconductor) image sensor, RF (radio frequency) transmitter, MCU (micro control unit), LED (light emission diode) lighting, and cell battery, as shown in Figure 3. After the CE is swallowed by patients, it will go through the entire GI tract with the natural peristalsis. During this course, the optical dome can plump up the intestine wall without requiring air inflation. In the meantime, the micro CMOS image sensor images the GI tract, and the RF model transmits the images outside of patient's body at the frame rate of 2f/s (frames per second). The images are received by the receiving box outside and showed in PC workstation. After the examination, the CE is vented out naturally. The CE is powered by a cell battery, which allows more than 6 hours of continuous working. The first human clinical trial was carried out in 2001, and the FDA was issued to M2A in August 2001 [7 ,8, 17].Such WCE offers a convenient examination with minimal preparation and immediate recovery. It is a realistic alternative to traditional wired invasive endoscopy and revolutionizes the methods of inspecting the GI tract. The name of M2A was changed to PillCam (means Pill and Camera) later. In 2005, Given Imaging developed two distinct WCE systems: PillCam ESO specially for the esophagus [18] and PillCam SB (fig 4) specially for the small intestine [19], as shown in Figure 3. The two kinds of CEs have the same architecture and the same working principle to M2A. PillCam SB is 11 × 26mm of outline and weights less than 4g, and its continuous working time is 7±1 hours. PillCam ESO has the same dimensions to PillCam SB and is equipped with miniature cameras on both ends. During the five-minute examination of passing down the esophagus, PillCam ESO has the capability of capturing 18 images per second, and its continuous working time is 20 ± 5 minutes. PillCam SB and PillCam ESO are replaced now by the second generations, which integrate advanced optics and automatic light control and so can provide optimal image quality and illumination.

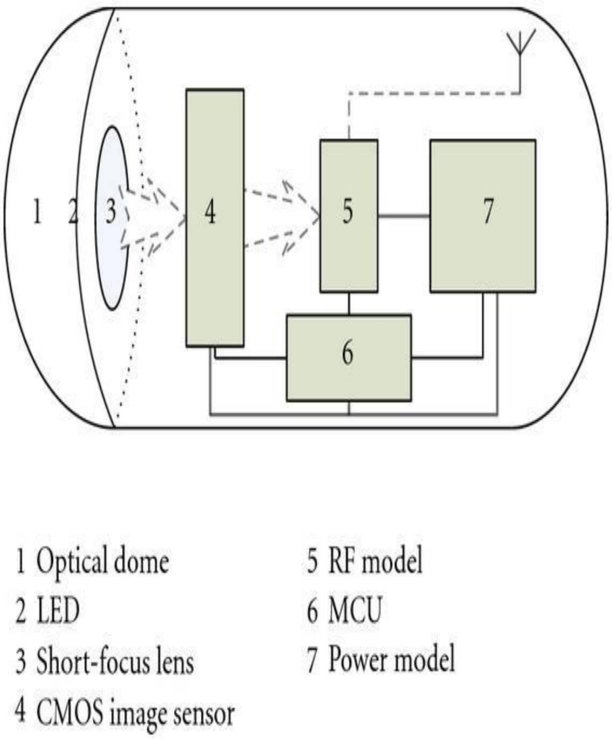

Figure 3: The architecture of CE

PROGRESS AND DEVELOPMENT: The WCE technology has been applied in clinic successfully, especially in the small intestine

Figure 4: Pillcam SB and Pillcam ESQ. diagnosis.

However, compared with wired endoscopy, the limited working time less than 8h, the low frame rate of 2f/s, and the low image resolution of 256×256 limit the wider application. Not only the working time is absolutely limited by the power supply of the CE, but the image resolution and the frame rate are also limited by the power supply. The parts, which consume most power, include the image sensor, the MCU, and the RF module.

One tendency of this novel technology is towards the high frame rate and high-resolution images. The living GI organs are constantly moving, and so the frame rate of 2f/s is obviously not enough for diagnosing the details of GI tract organs. The ideal frame rate of WCE is as high as video WCE. Now, some video WCE systems have been developed, and the CE can transmit GI tract images with the frame rate of 30f/s in NTSC video format [31]. On the other side, the image resolution of 256 × 256 is not satisfied compared with wired endoscopy, and the image resolution cannot be too higher any more. However, the high frame rate and high image resolution consequently bring much more power needed which is beyond any cell battery can supply. In order to reduce the image data for the high image resolution and high frame rate, some new image compression algorithms were developed for video CE [32, 33]. However, the complex compression algorithm is not suitable for the tiny and low-power CE, and the effects are limited. Wireless power transmission (WPT) is the right solution for this problem, but it is not easy, and so it is one big technical challenge. The wireless electric power transmission system [4] is based on electromagnetic induction. Such WPT system has been successfully applied in TET (transcutaneous energy transmission) systems to provide power for some implanted artificial organs [34–36]. But the existing technology for TET systems is not suitable for WCE. In TET systems, the transmitting coils (TCs) and receiving coils (RC) are placed as nearly as possible, and the distance between them is not more than 20mm. However, the TC and RC in WCE system are placed out and in the body, and the distance between them is 50mm∼150mm. The longer the distance is, the weaker the transmitting electromagnetic field becomes, so the electric power generated in RC is very limited.

Another tendency of WCE progress is the active CE, namely, the capsule robot. Now in the existing WCE system, after being swallowed, the CE travels ahead with the GI tract natural peristalsis, and so the CE locomotion is passive. Consequently, the position cannot be controlled, which is the main drawback of the WCE technology. Because of the passive locomotion of the CE, the focus of disease cannot be viewed repeatedly. Moreover, the passive locomotion is the bottleneck of the novel CE with various

ISSN (Online) 2394-6849

International Journal of Engineering Research in Electronics and Communication Engineering (IJERECE)
Vol 6, Issue 5, May 2019

functions including biopsy and drug delivery. The active CE will be the next generation of the passive CE.

Usage of Wireless Capsule Endoscopy:

• Find the cause of gastrointestinal bleeding. If you have unexplained bleeding in your digestive tract, capsule endoscopy can help find the cause.

• Diagnose inflammatory bowel diseases, such as Crohn's disease. Capsule endoscopy can reveal areas of inflammation in the small intestine.

• Diagnose cancer. Capsule endoscopy can show tumors in the small intestine or other parts of the digestive tract.

• Monitor celiac disease. Capsule endoscopy is sometimes used in monitoring this immune reaction to eating gluten.

• Screen for polyps. People who have inherited syndromes that can cause polyps in the small intestine might occasionally undergo capsule endoscopy.

• Do follow-up testing after X-rays or other imaging tests. If results of an imaging test are unclear or inconclusive, your doctor might recommend capsule endoscopy to get more information.

Precautions before test:

To prepare for your capsule endoscopy, your doctor is likely to ask that you:

• Stop eating and drinking at least 12 hours before the procedure. This will ensure that the camera captures clear images of your digestive tract.

• Stop or delay taking certain medications. To keep medication from interfering with the camera, your doctor might ask you not to take certain medications before the procedure. In other cases, your doctor will want you to take your medication two hours before or after you swallow the capsule that contains the camera [1].

Plan to take it easy for the day. In most cases, you'll be able to go about your day after you swallow the camera capsule. But you'll likely be asked not to do strenuous exercise or heavy lifting. If you have an active job, ask your doctor whether you can go back to work the day of your capsule endoscopy.

During capsule endoscopy:

On the day of your capsule endoscopy, your health care team will go over the steps in the procedure with you. You might be asked to remove your shirt so that adhesive patches can be attached to your abdomen. Each patch contains an antenna with wires that connect to a recorder. Some devices don't require the patches.

You wear the recorder on a special belt around your waist. [4]The camera sends images to an antenna on your abdomen, which feeds the data to the recorder. The recorder collects and stores the images.

Once the recorder is connected and ready, you swallow the camera capsule with water. A slippery coating makes it easier to swallow. Once you swallow it, you shouldn't be able to feel it.

You'll then go about your day. You can drive, and you might be able to go to work, depending on your job. Your doctor may recommend some restrictions, such as avoiding strenuous activity, including running and jumping.

After the capsule endoscopy:

Wait two hours after you swallow the capsule to resume drinking clear liquids. After four hours, you can have a light lunch or a snack unless your doctor tells you otherwise.

The capsule endoscopy procedure is complete after eight hours or when you see the camera capsule in the toilet after a bowel movement, whichever comes first. Remove the patches and the recorder from your body, pack them in a bag and follow your doctor's instructions for returning the equipment. You can flush the camera capsule down the toilet.

Your body might expel the camera capsule within hours or after several days. [2] Each person's digestive system is different. If you don't see the capsule in the toilet within two weeks, contact your doctor. Your doctor might order an X-ray to see if the capsule is still in your body.

Diseases detected by capsule endoscopy:

Capsule endoscopy continues to improve technically. It has revolutionized diagnosis by providing a sensitive (able to identify subtle abnormalities) and simple (non-invasive) means of examining the inside of the small intestine. Some common examples of small intestine diseases (fig 5) diagnosed by capsule endoscopy include:

- Angiodysplasias (collections of small blood vessels located just beneath the inner intestinal lining that can bleed intermittently and cause anemia)
- Small intestinal tumors (fig 6) such as lymphoma, carcinoid tumor, and small intestinal cancer
- Crohn's disease of the small intestine.

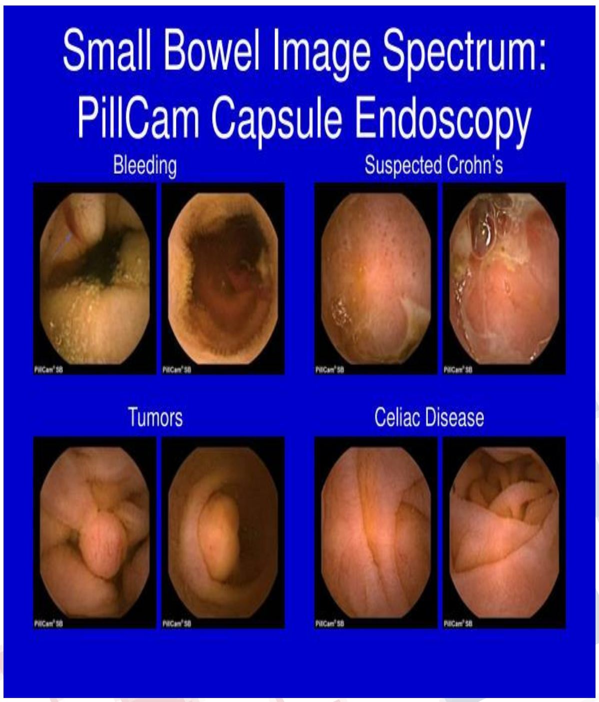

Figure 5: various diseases detected by capsule endoscopy.

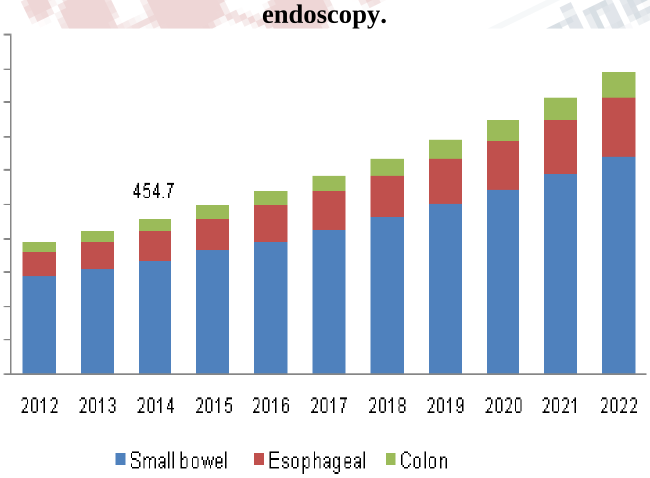

Figure: market analysis

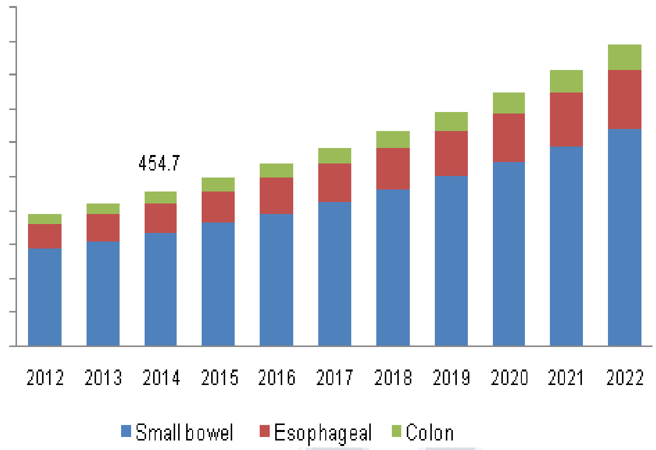

Figure 6: Tumors of small intestine detected by capsule endoscopy.

CONCLUSION

WCE offers a feasible non -invasive way to detect the entire GI tract and brings about a revolution in the diagnosis technology of GI diseases. Unfortunately, compared with wired endoscopies, the limited working time, the low frame rate, and the low image resolution limit the wider application. Therefore, the tendencies of the WCE progress are the WCE with high image resolution, high frame rate, and long working time. However, the power supply of CE is the bottle neck[5] of this tendency. WPT is the promising solution to this problem, but is also the technical challenge. Many achievements about the WPT technology have been gotten, but the research efforts are still needed on the safety and transmission efficiency. Active CE is another tendency and will be the next generation of the WCE, but not shortly. The medical robot, which integrates the multi functions of the endoscopy, the biopsy, the drug delivery, and the microsurgery, is the optimal diagnostic and therapeutic instrument of GI diseases. However, the locomotion mechanism of it in GI tract is the other technical challenge, besides the challenge of WPT. Some novel and imaginative locomotion mechanisms are proposed, but none of them is practicable to be applied in clinic. Therefore, the novel and practicable locomotion mechanism of the active CE in GI tract, as well as the WPT technology, must be achieved before the clinical application, which is the premise of the active CE.

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