Wireless Capsule Endoscopy: A Brief Review

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ABSTRACT
Traditional wired endoscopic devices are used for stomach and colon inspection. However, Capsule Endoscopy (CE) is a significant medical device for investigating the small bowel, where the Wireless CE (WCE) offers visual inspection of the whole gastrointestinal (GI) tract. The WCE has revolutionized the diagnostic process of small bowel diseases. Thus, it becomes the leading screening system for the entire GI tract. The WCE is considered as a promising system that overcomes the limitations of the traditional diagnosing equipment including comfortlessness due to cables and the incapability of investigating small intestine sections. In order to enhance the WCE, computational techniques can be implemented for accurate capsule localization and tracking. Accurate knowledge of the WCE position indicates the abnormality position has a fundamental role for different reasons, including accurate localization of lesions and automated CE navigation. Typically, the WCE system includes developments to manage the capsule instantaneous localization process.

Keywords: Capsule Endoscopy, Wireless Capsule Endoscopy, Gastrointestinal, Complementary metal–oxide–semiconductor, Received Signal Strength.

1. INTRODUCTION

1.1 Gastrointestinal Medical Image Acquisition Using Endoscopy

The first wireless endoscopic system is the WCE that was launched in 2001 as a clinical product termed M2A by Given Image Ltd. The 11mm x 26mm M2A capsule is illustrated in Figure 1. [1], where the M2A capsule components include the lens holder, optical dome, lens, Complementary metal–oxide–semiconductor (CMOS) imager; illuminate LEDs, battery, RF transmitter and the antenna. Initially, this active WCE is swallowed by the patient to start capturing photos through its movement in the GI tract. It passively traverses the food tract by ordinary peristaltic GI system movement until it reaches the colon. The captured images are relayed through the transmitter using an RF signal to the attached antenna array in the patient's body. Afterwards, this signal is conveyed to a data-recorder worn on a belt. Inside the patient's body, the position triangulation of the capsule is monitored by the sensor array so that the capsule path trajectory can be later presented on a monitor. The patient's examination initiates by attaching antennas to the chest of the patient to be coupled to the worn data-recorder. Immediately, the capsule acquires images though the RF transmission. Nevertheless, it takes long time for the capsule to go through the whole GI tract. Finally, the WCE is reflexively ejected from the human body.

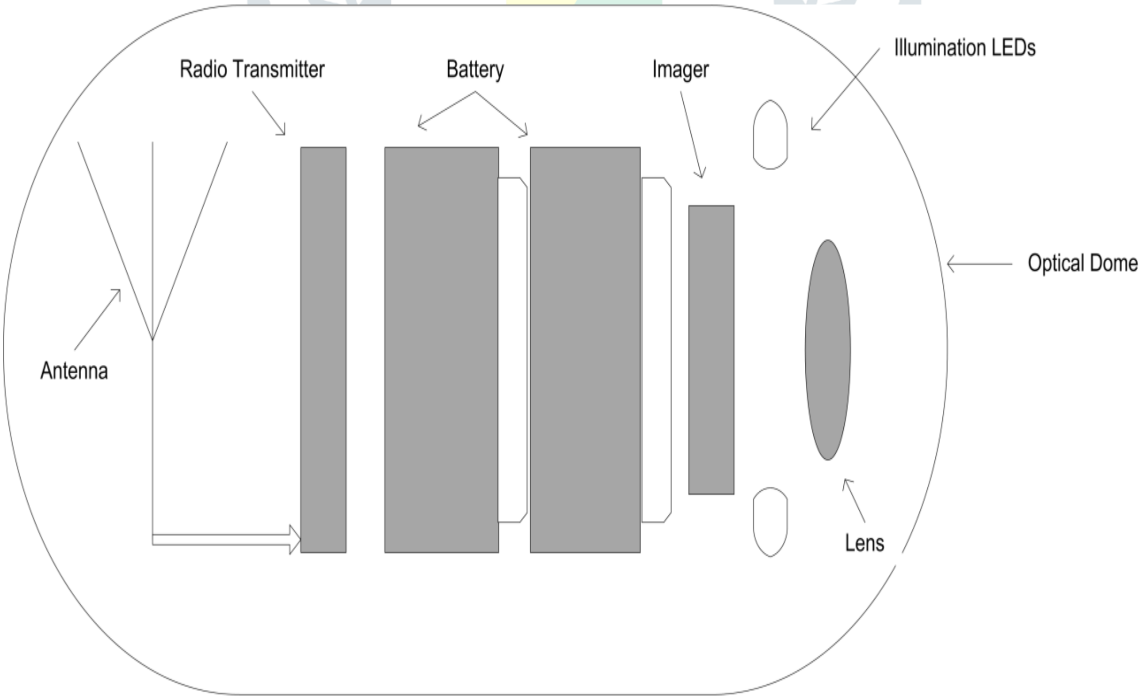

Figure 1.1: Capsule Endoscopy

However, this effective method suffers from relatively high power consumption of the camera and RF components, which leads to a limited 8-12 hours WCE lifetime to examine the small intestine and large intestine. Increasing functionality is a critical requirement for endoscopic system platforms. The image sensor and processing interpolation/engine systems are significant to achieve effective resolution. Typically, endoscopic system equipment necessitates increased processing performance, where image sensor technology develops higher resolution streams [2]. Furthermore, it is difficult to control the capsule's location/orientation, which may lead to missing the captured images of some spots [1]. In order to manage these limitations, a new wireless robotic capsule endoscope system can be employed to control the movement of the capsule externally.

1.2 WCE Localization

Colonoscopy dominated the market for several years before the invention of WCE. It was considered the main procedure to conduct GI tract; however, it is unable to offer inspection inside the small intestine. Compared to the colonoscopy, WCE offers a comfortable, non-invasive and non-embarrassing method to inspect the patients' GI tract. The WCE device records images of any abnormalities inside the GI tract at a comparatively high rate to assist physicians diagnose and plan treatment. The WCE RF and visual localization accuracy is a critical issue, thus Zhou [4] attached two miniature cameras to the capsule in order to capture thousands of images during the capsule path through the GI tract. The captured images have a frame rate that varies from 2 to 8 frames/second to perform pseudo video. The most significant aspect of a WCE examination is to determine the accurate capsule position in order to recognize the detected intestinal abnormality/disease position. Consequently, several localization systems have been developed to precisely localize the WCE. The magnetic field methods, TOA-based methods, video-based methods, RSS-based techniques and the video-aided hybrid localization methods are different localization approaches. The RF localization possibility of the WCE has been discussed [5]. The localization of WCE using RF signals is particularly complex due to the complicated environment inside the human body. The RSS localization accuracy inside the human body has been previously considered [6] resulting in an average 50mm localization error in the human GI tract. In addition, the impact of the topology and the number of sensors on the localization accuracy need to be investigated further. Moreover, researchers have been interested in TOA-based WCE localization. The foremost challenge for TOA-based localization of WCE is the mass of the human body. There are two directions in the TOA- based localization for heterogeneous tissue to find the signal trace and homogeneous tissue to conduct simulations. Furthermore, recently one of the evolving localization methods is the Phase Difference of Arrival (PDOA). Previously, for Body Area Network (BAN) localization, the PDOA has been considered as an inappropriate localization technique due to ambiguity. However, for in-body circumstances, the range between the transmitter and the receiver can be within several centimeters thus enhancing the opportunity of using PDOA.

2. EARLY ENDOSCOPIC DEVICES ANALYSIS

Early endoscopic devices were lit by external inflexible light sources. Therefore, they were limited in terms of their usability. Subsequently, more modern endoscopes have become very compact one small diameter flexible tube devices, including a light source, CMOS chip or a charge-coupled device (CCD) for capturing images of the GI tract, and other equipment to take tissue samples. These endoscopes were unequipped with a digital imaging chip, but with an eyepiece lens and fiber optics. Imaging abilities, including illumination, modality and sensor characteristics are considered the most significant features in designing WCE systems [3]. The sensor/lens position determines the region imaged by the WCE. Most of the image sensors are attached to the capsule. Lenticular lens arrays or microlens arrays are established in laparoscopic surgery to deliver a multi-view image using a single sensor. Generally, the capsules should offer a widespread Field of View (FoV) to detect an adequate image of the tissue walls [7]. In the capsule design, the telemetry subsystem forms a bottleneck due to the size constraint limitations of the wireless communication system. Furthermore, video-based motion tracking is a critical issue, where at least one camera is used to equip the WCE to offer visual inspection of the GI tract and to track the capsule movement. However, the inspection of the GT using the traditional endoscope is considered uncomfortable procedure for the patient along with the potential side effects, such as infection, organ perforation, and hemorrhage. Consequently, there is much research to cope with these difficulties. Exclusively, the small intestine is problematic due to its very long and convoluted path. Thus, the endoscope cannot be used to examine the entire length of the small intestine. This leads recently to develop a superior diagnosis tool for the small intestine, namely the wireless capsule endoscopy (WCE). This WCE is basically contains a lens, light source, radio transmitter, camera, and batteries. Afterward, the capsule travels via the digestive system, driven by peristalsis, and automatically captures a massive number of images during the eight hours traveling time. These images are wirelessly transmitted to a recorder/receiver worn outside the patient's body [8]. Traditional wired endoscopic devices are used for stomach and colon inspection. However, Capsule Endoscopy (CE) is a significant medical device for investigating the small bowel, where the Wireless CE (WCE) offers visual inspection of the whole gastrointestinal (GI) tract. The WCE has revolutionized the diagnostic process of small bowel diseases. Thus, it becomes the leading screening system for the entire GI tract. The WCE is considered as a promising system that overcomes the limitations of the traditional diagnosing equipment including comfortlessness due to cables and the incapability of investigating small intestine sections. In order to enhance the WCE, computational techniques can be implemented for accurate capsule localization and tracking. Accurate knowledge of the WCE position indicates the abnormality position has a fundamental role for different reasons, including accurate localization of lesions and automated CE navigation. Typically, the WCE system includes developments to manage the capsule instantaneous localization process. The received signal transmission and attenuation are examined using an antenna array in the human body environment. Additionally, the connotation between the capsule location, capsule's transmitter position, signal reduction and the capsule direction are also assessed.

3. CONCLUSION

Bleeding detection in gastrointestinal (GI) tract is one of the important tasks for diagnosing different GI diseases from clinical and physician point of view. The main body of GI tract cannot be reached by traditional endoscopies because of its respective limitations. However, wireless capsule endoscopy (WCE) has been proven to be the best choice of investigation for visualizing the entire small bowel. The problem of WCE lies in its reviewing process which usually takes two hours to complete. Furthermore, there may be some bleeding regions and abnormal characters which cannot be recognized by naked eyes due to their size or distribution. All these problems motivate researchers to develop the computer aided intelligent bleeding detection technology to reduce the burden of physicians.

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