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Low power design of wireless endoscopy compression/communication architecture

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Abstract

A wireless endoscopy capsule represents an efficient device interesting on the examination of digestive diseases. Many performance criteria's (silicon area, dissipated power, image quality, computational time, etc.) need to be deeply studied.

In this paper, our interest is the optimization of the indicated criteria. The proposed methodology is based on exploring the advantages of the DCT/DWT transforms by combining them into single architecture. For arithmetic operations, the MCLA technique is used. This architecture integrates also a CABAC entropy coder that supports all binarization schemes. AMBA/I2C architecture is developed for assuring optimized communication.

The comparisons of the proposed architecture with the most popular methods explained in related works show efficient results in terms dissipated power, hardware cost, and computation speed.
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Keywords: Wireless endoscopy capsule; DCT/DWT image compression; CABAC entropy coder; AMBA/I2C multi-bus architecture

1. Introduction

An endoscopic system is an efficient device in medical applications due to its ability to examine the digestive disease accurately. However, it is inconvenient to use in a traditional wired endoscopy since it causes considerable discomfort to patients. Also, due to its finite length, this system is limited in terms of test coverage (Singeap et al., 2016). Moreover, in the long small intestine, it cannot simply access all of the digestive organs. Therefore, many new endoscopy examination techniques, such as ultrasound and wireless schemes, have been proposed (Chi et al., 2006). Among them, the capsule developed by Iddan et al. (2000) represents the first wireless system that is used rather than wired endoscopy. It could be small enough to be swallowed by patients without causing any discomfort.

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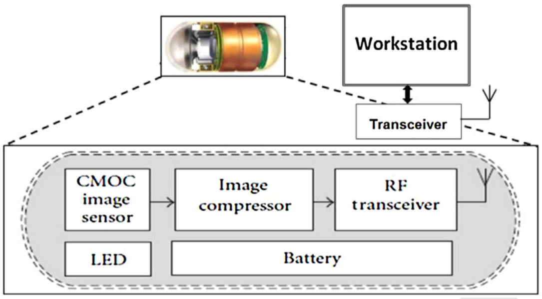

Fig. 1. Block diagram of a typical endoscopic system.

And, the capsule system has the advantage of allowing a direct examination of the digestive disease with no anesthesia (Glukhovsky, 2003; Wang et al., 2007). Therefore, many radio frequency (RF) endoscopy systems have been developed in the 433/868/915 bands (Quinlan, 2004) or 2.4 GHz bands (Fakher et al., 2004).

The first commercialized capsule endoscope has been developed in 2000 (Pillcam, 2011). In 2006 an extended capsule dedicated to the screening of colorectal diseases has been proposed (Moglia et al., 2008). Some other companies such as Olympus, Pentax, and Siemens entered into the market with similar products (McCaffrey et al., 2008; Moglia et al., 2008).

Fig. 1 below presents a typical wireless endoscopic system. It represents electronic capsule, a workstation, and a wireless link. The capsule to be swallowed by the patient is hermetically packaged. Two LEDs are integrated into the capsule to illuminate. The output data image from the compressor that is captured by the CMOS sensor are submitted by a wireless RF transmitter to outside of the body where they are received and memorized in order to be reconstructed for subsequent diagnosis. The controller commands the compressor operations according to operator's instructions entered from the workstation.

Wireless capsule uses a tiny wireless camera to take pictures of the digestive tract and it is taking about 50,000–60,000 digital images for the doctor's review. The capsule endoscopy needs to be small enough to be swallowable easily and to pass through human GI tract. Generally, it takes 24 h to move from mouth to evacuation. These images are transmitted by a wireless radiofrequency transmitter to outside of the body in the workstation, where they are stored (Moglia et al., 2008). Although the transmission of the image data occupies about 90% of the total power in the capsule endoscopy (Moglia et al., 2008). The data should be first compressed to reduce the power of the image data transmitting and the communication bandwidth. Yet, it is necessary to save the resolution of the constructed image because the images may be distorted while physician applies zooming to perform detailed diagnosis (Kinde et al., 2016). Whereas increasing the resolution causes huge increase in power consumption in the RF transmission.

The organization of the paper is presented as follow. Section 2 introduces and discusses the related works. Section 3 describes all steps and methods of the architecture design. The experimental results are shown in Section 4. Section 5 discuss these results and compare them with related works. Finally the conclusion is shown in Section 6.

2. Related works

The principal concern during the design of a wireless endoscopy system is to ameliorate the performances (power, area, computational speed, etc.). For this reason, we have interested principally on the optimization of the main part (image compression) of the endoscopy system. Firstly, we have adopted the DCT based technique. In fact, up to here, there are many works who are interested on this technique (Loeffler et al., 1989; Li and Lu, 1996; Park et al., 2002; Shams et al., 2002; Amer et al., 2005; Park and Ogunfunmi, 2009). In Amer et al. (2005), authors propose a high performance hardware implementation of the 8×8 transform. The proposal is designed to perform pipelined computation and reduce the required memory resources and accesses. Reference Park and Ogunfunmi (2009) provides a FPGA architecture supporting the real-time constraints and proposes a reduced parallel architecture in order to optimize resources constraints. Architecture for adaptive block size 8×8 and 4×4 transform is developed in Park et al. (2002). In Loeffler et al. (1989), Loffler presents an optimized DCT algorithm that performs 11 multiplications and 29 additions for computing the DCT of an 8 points vector. This algorithm usually performs arithmetic operations by using the floating point technique, so it consumes a lot of memory and power. In the last few years, a simplified

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