LOW-COMPLEXITY IMAGE COMPRESSION FOR WIRELESS CAPSULE ENDOSCOPY AND POLYP DETECTION IN COLONOSCOPY VIDEOS

KINDE ANLAY FANTE

DEPARTMENT OF ELECTRICAL ENGINEERING

INDIAN INSTITUTE OF TECHNOLOGY DELHI

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by

KINDE ANLAY FANTE
Department of Electrical Engineering

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Certificate

This is to certify that the thesis entitled **"Low-Complexity Image Compression for Wireless Capsule Endoscopy and Polyp Detection in Colonoscopy Videos"**, being submitted by **Mr. Kinde Anlay Fante** for the award of the degree of **Doctor of Philosophy** to the Department of Electrical Engineering, Indian Institute of Technology Delhi, is a record of bonafide work done by him under our supervision and guidance. The matter embodied in this thesis has not been submitted to any other University or Institute for the award of any other degree or diploma.

Dr. Basabi Bhaumik
Professor,
Department of Electrical Engineering,
Indian Institute of Technology Delhi,
Hauz Khas, New Delhi - 110016,
INDIA.

Dr. Shouri Chatterjee
Associate Professor,
Department of Electrical Engineering,
Indian Institute of Technology Delhi,
Hauz Khas, New Delhi - 110016,
INDIA.

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Abstract

Medical imaging plays indispensable role in modern medicine. Most of the modern disease diagnosis systems employ medical imaging. The medical imaging modalities includes magnetic resonance imaging (MRI), X-ray, ultrasound, endoscopy, etc. In this thesis, we focus on optical endoscopy which is widely used to screen the human gastrointestinal tract. The work presented in this thesis can be divided into two parts. In the first part, we deal with the challenge to design low-complexity image compression algorithms for wireless wireless capsule endoscopy (WCE). In the second part, we present automatic polyp detection and localization system in colonoscopy video.

Wireless capsule endoscope is a recent breakthrough in diagnosis of gastrointestinal abnormalities. It consists of swallowable capsule, data recorder and workstation. The capsule itself comprised of a camera, battery and radio frequency (RF) transmitter. The RF transmitter consumes the highest portion of the total battery power to transmit the captured color image of gastrointestinal (GI) tract to the data recorder. One of the methods which is employed to elongate the lifetime of the capsule is to incorporate image compression system inside the capsule. Due to the constraints on computational complexity, power consumption and image quality it is necessary to design efficient image compression algorithm for this application. This goal is achieved by exploiting unique structures which exist in endoscopic images. Two image compression architectures are designed and implemented in this work.

The first image compression scheme is designed to compress full color endoscopic images. The scheme comprises of a combination of computationally simple methods, uniform quantization, color space transformation, differential pulse-coded modulation and locally adaptive Golomb-Rice codes. These methods are heavily optimized from the computational complexity and efficiency perspectives. The algorithm achieves a compression rate of 90.35 $\%$ with peak signal-to-noise ratio (PSNR) of 40.66 dB. The prototype integrated circuit implementation in 130 nm standard CMOS process consumes an average power of $35\ \mu W$, for encoding two full color frames with a resolution of 256×256, and occupies a

silicon area of $0.018\ mm^2$.

The second image compression system is designed to compress color mosaic endoscopic images. It comprises the optimal combination of uniform quantization, discrete wavelet packet transformation, differential coded modulation scheme and locally adaptive Golomb-Rice entropy coder. The algorithm achieves a compression rate of 81.31 % with PSNR of 39.45 %. The prototype integrated circuit implementation of the algorithm in 130 nm standard CMOS process consumes an average power of $48.4\ \mu W$ for encoding two frames of 512×512 resolution. It occupies silicon area of $0.342\ mm \times 0.342\ mm$.

The second part of this thesis focuses on polyp detection and localization in colonoscopy video. Colorectal cancer is the third leading cause of cancer-related deaths worldwide. Its most effective preventive method is to detect and remove polyp early before it develops into cancerous stage using colonoscopy. The accuracy of polyp detection depends on experience, fatigue and attentiveness of the colonoscopist during the procedure. Computer-aided polyp detection system can assist the colonoscopist to reduce polyp miss rate. Polyp detection is a difficult task due to its variation in appearance, size, shape and texture. Designing feature extractor which is invariant to these variation of polyp is not a trivial task. To overcome this difficulty, we propose a polyp detection system which is based on data-driven approach using Convolutional Neural Networks (CNN). We use the capability of CNN that it learns the optimal features that discern different classes of images from labeled images automatically. A deep CNN model is trained on large polyp database and achieves a classification performance of 75.21 % sensitivity, 92.69 % specificity, and 89.56 % accuracy.

The polyp detection algorithm is extended to the polyp localization in colonoscopy video frames. It uses image segmentation and CNN. A frame of colonoscopy video is segmented and small patches are extracted. The image segmentation is done using Log-Gabor filter and edge detector. The CNN model is trained and classify the patches as a patch with polyp or normal patch. The proposed computer-aided detection system shows a promising polyp localization performance of 86 % sensitivity, 89.85 % specificity, and 88.44 % accuracy.

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