CHAPTER 1: INTRODUCTION

1.1 Introduction

This study examines problems related to medical image analysis in capsule endoscopy from the perspective of computer vision and machine learning. Further, it aims to propose intelligent techniques for the design and development of an automatic abnormality detection system for the diagnosis of gastrointestinal tract diseases from capsule endoscopy images. This chapter sets the required background for the research and provides an introduction to the study. It also provides a brief organization of the thesis.

1.2 Background

Diseases related to Gastrointestinal (GI) tract such as ulcer, angioectasia, bleeding, cancer, motility, Chron's disease, and many more are a significant threat to the health of human beings. GI cancer is not only one of the most common cancers but also one of the most common causes of cancer mortality [1]. GI tract diseases are diagnosed mainly by endoscopic procedures namely push endoscopy, enteroscopy, intra-operative endoscopy and capsule endoscopy [3]. Capsule endoscopy (CE) is a non-invasive, non-sedative, disposable and painless alternative to conventional endoscopy procedure [2]. With upper endoscopy and colonoscopy, visualization of the entire small intestine is not possible, while the CE provides a comfortable and efficient way to visualize the entire GI tract [3]. Gradually its wide application in hospitals is seen in the last few years because it can be used to view the entire GI tract without invasiveness, sedation, radiation or air-inflation. The capsule is a swallowable endoscopic device with 11 × 26 mm dimensions and 3.7 g weight that is ingested and propelled by natural peristalsis through the GI tract [4]. Figure 1.1 shows length and various components of the capsule.

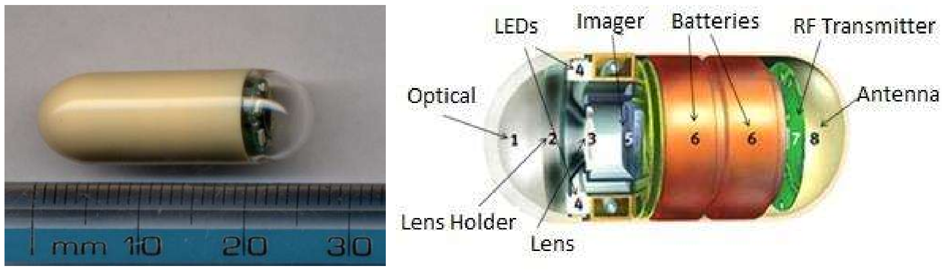

Figure 1.1: Capsule length and components [5][6]

The capsule contains light-emitting diode (LED)s, one or two video chips (cameras), batteries and a radio transmitter. The patient swallows a capsule. As the capsule travels through the GI tract - esophagus, stomach, and small intestine, it takes photographs at a frame rate of 2 fps (frames per second). The radio transmitter transmits the photographs to a receiver worn on the waist of the patient who is undergoing the CE procedure. Figure 1.2 depicts a brief overview of the capsule endoscopy system. At the end of the procedure, approximately 8 hours later, the photographs are downloaded from the receiver into a computer, and a physician reviews the images. The capsule is passed by the patient into the toilet and flushed away. There is no need to retrieve the capsule. Thereby the concerns related to hygiene are automatically addressed.

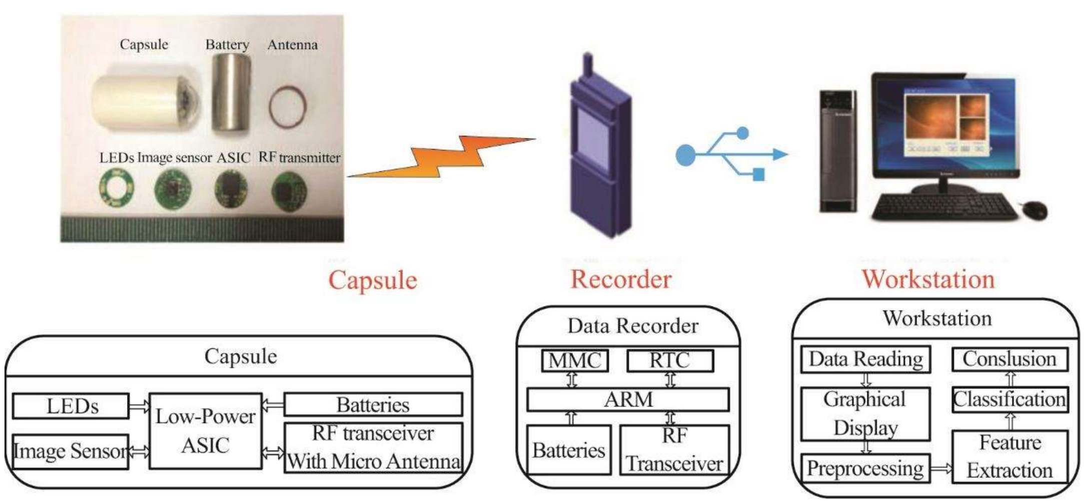

Figure 1.2: Capsule endoscopy system [7]

Stepwise procedure for CE is as follows:

1. A receiver belt is tied on the waist of the patient.
2. The patient swallows the capsule preferably empty stomach.
3. The capsule propels through the entire GI tract by natural peristaltic moments.
4. The capsule keeps on transmitting the data of the GI tract at a frame rate of 2 fps.
5. The receiver receives and stores the data.
6. The process continues till the batteries last or till the capsule is naturally disposed out of the GI tract.
7. The receiver's stored data is then copied to a computer by a USB device.
8. The physicians then view and analyze the video.

CE is a very patient-friendly and convenient procedure however, it produces a huge amount of data but, only a limited amount of data is used for diagnosis. The length of the CE video ranges from 6 to 8 hours producing approximately 60000 images at the rate of 2 fps [8]. For an expert to examine such lengthy videos precisely is both time consuming and tedious. In addition to a huge number of frames, GI tract appearance, intestinal dynamics and need of constant concentration further complicate the diagnostic and analysis procedure. Also, the examination is highly subjective in nature and will vary as per the individual's expertise and experience. Thus a computer-aided diagnosis system is a must. Further with advancements of IoT (Internet of Things), such a tool can be of significant importance in remote diagnosis for patients of geographically distant locations where an expert may not be available.

This study is related to the development of an automatic abnormality detection system for detecting GI tract abnormalities from a CE procedure. The challenges faced in this domain are:

- Lack of ground truth data in the public domain.
- Highly skewed data. Very few frames have abnormality in the entire CE video except in a very critical case such as an advanced stage of cancer.
- The same set of features is insufficient to detect various types of abnormalities.
- It is a multi-class classifier problem. It is not limited to a binary problem such as normal vs. abnormal.
- A high dimensional feature vector makes the problem even more complex.
- It is an interdisciplinary problem which requires input from medical as well as engineering fields.

1.3 Motivation

Challenges from the perspective of a physician:

- 6 to 8 hours long videos.
- Time-consuming & tedious task.
- Need for constant concentration.
- Highly complex and subjective GI tract.
- Hardly 1-2% [8] of frames out of 60,000 are important.
- Hardware inherent limitation such as poor image quality & poor illumination.

One-third of the world population suffers from GI tract abnormalities such as ulcer, bleeding, cancer, Chron's disease and many more. After the brain, the maximum number of neurons is present in the enteric nervous system hence it is also referred to as the "second brain" [2][3]. This enteric nervous system controls the GI system and it is highly complicated. As per WHO Globocan data 2012 (India) [1], 22.7% of cancers are located in the GI tract and 26.6%

deaths were caused due to GI cancer. Other diseases will certainly add to the statistics. This scenario has served as a motivation for me to carry out this research.

1.4 Problem Statement

The aim of this thesis is to apply computer vision and machine learning approaches to design and develop an automatic abnormality detection system for capsule endoscopy.

1.5 Contributions and Objectives of the Thesis

The objectives of the study are as follows:

(i) To conduct a rigorous literature review on this topic including the peripheral sub-topics

(ii) To propose a mechanism for restoration and enhancement of CE images

(iii) To develop a generic segmentation technique for CE images

(iv) To propose a feature selection and data reduction technique

(v) To propose a system for automatic abnormality detection in CE

The brief contribution of this thesis are as follows:

(i) Comparison of state-of-the-art methods for all aspects of medical image analysis in CE

(ii) A framework for restoration and enhancement of CE images

(iii) An effective approach for segmentation of all types of CE images

(iv) Design and development of an efficient feature selection and data reduction technique

(v) Design and development of an efficient algorithms for the CAD system by using a combination of transfer learning and conventional machine learning approaches

1.6 Organization of the Thesis

This thesis consists of seven chapters. Outline of the thesis is as follows:

Chapter 1 presents a brief introduction of the problem followed by the motivation and objectives of the thesis

Chapter 2 discusses the theoretical background of all aspects of medical image analysis in capsule endoscopy. Further, this chapter presents a comprehensive literature review

Chapter 3 presents a framework for the restoration of capsule endoscopy images using partial differential equations based filters

Chapter 4 presents an improved Gaussian Mixture Model-based generic segmentation technique for capsule endoscopy

Chapter 5 presents a high variance low correlation-based data reduction and feature selection approach in case of ulcer detection in capsule endoscopy

Chapter 6 presents a multi-class classifier system for capsule endoscopy using conventional machine learning and deep learning

Chapter 7 presents conclusions of the thesis and summarizes main findings of this work with possible future perspectives of the study