AUTOMATIC DETECTION OF POLYPS FROM ENDOSCOPIC IMAGES

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Abstract

Polyps are considered as growing tissues on the surface of intestinal tract not inside of an organ. Polyp identification in human Gastro Intestinal (GI) Tract employing endoscopy and colonoscopy through various computer vision and image processing techniques achieved lot of success and maturity in its field. Polyps in gastrointestinal (GI) tract can be precursors to cancer and detecting them early is important in determining their malignancy. Colorectal polyps are important precursors to colon cancer, a major health problem. A critical problem associated with endoscopy and colonoscopy examination is to localize and correctly estimate the size of polyps for proper clinical treatment. In this thesis a colour-based segmentation technique followed by connected components features is proposed to extract and detect polyp regions from endoscopy frames. The proposed colour-based segmentation method is carried on the R channel of input RGB frame, considering the colour features of polyp regions. Examining the pixel values of polyp and non-polyp region a thresholding is carried out. Next, pixel connectivity across the resultant threshold binary image, based on area of the connected component leads to to extract successful polyp regions. This proposed method is applied on the frames containing polyps which is obtained from Kvasir dataset (open source bio-medical dataset) and it successfully segmented the polyp region with an accuracy of 93.27%. The experimental results of this approach is verified by expert physicians from Medica Super Specialty Hospital Kolkata and the proposed method also show its improvement of accuracy when compared with other methods in the literature.

CHAPTER 1

CHAPTER 1

INTRODUCTION

1.1 Digital Image Processing

An image is a 2D signal which is defined by a mathematical function f (x, y).x and y are horizontal and vertical coordinates. The intensity of an image at the point is defined by (x, y). So in other words image can be defined by 2D array. A digital image is defined by a finite number of rows and columns. Each element is defined by a particular position. These elements are called pixels. [1]

Digital image processing is a technique that can convert an image into digital form and perform some operations on it. Digital image processing includes importing images (image acquisition), analysis images, report based on images. Main tasks of digital image processing are – improvement of images for human interpretation and processing of data from an image for storage, machine interpretation.

First applications of digital image processing were in the newspaper industry in 1920. Images were transferred by submarine cable services from London to New York by Bartlane cable picture transmission service. First digital image processing was developed in 1960 at the Massachusetts Institute of Technology, Jet Propulsion Laboratory, Bell Laboratories, University of Maryland, and a few other research centers. In 1964 computers are used to improve the image quality [2]. First digital image processing was used in the medical field in 1970. Sir Godfrey N. Hounsfield & Prof. Allan M. Cormack shared the Nobel Prize in medicine for the discovery of tomography in 1974.

Image processing consists of the following steps. Image acquisition is the primary step of the digital image process. It can be as easy as being given a picture that's already in digital type. Generally, the image acquisition stage involves pre-processing, scaling, noise removing, etc. The second step is image enhancement. Image enhancement is the simplest areas of digital image process. Basically, the concept behind enhancement techniques is to highlight detail that's obscured, or just to find out a region of interest in a picture. Such as changing brightness, contrast, etc.[3].The third step is Image restoration which deals with improving the image appearance. Restoration techniques are based on mathematical and probabilistic models of image degradation. Colour image processing is also a part of digital image processing and an area that includes color modeling and processing in a digital domain. Wavelets are used for representing images in various degrees of resolution. In wavelet and multiresolution processing, images are subdivided into multiple data and represent as a pyramidal structure. Compression deals with techniques for reducing the storage needed to save lots of a picture or the information to transmit. Morphological processing is used for extracting image components that are useful in the representation and description. Segmentation procedures partition an image into small parts. Representation and description follow the output of a segmentation stage, which usually is raw pixel data, constituting either the boundary of a region or all the points in the region itself. Object recognition is the process to identify an object from images based on its properties. After completing all steps of image processing, new data is stored in the knowledge base, as shown in Fig. 1.1

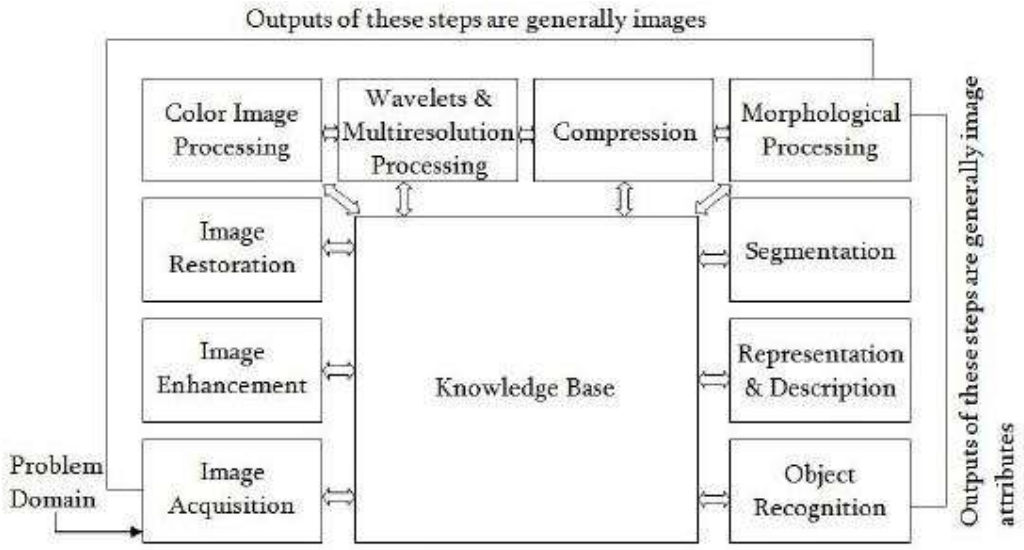


Fig. 1.1 Steps of digital image processing

Applications of digital image processing -

The field of digital image processing has experienced continuous and vital growth in recent years[4]. It plays an increasingly important role in science and technology and also in our daily life. Digital image processing is a computer-based technology that facilitates the automatic detection of objects and desired regions. Some of the major fields where digital image processing is applied are mentioned below-

- Medical Application-Digital image processing is widely used in medical fields. Gamma-ray imaging, Pet scan-ray imaging, CT scan, UV imaging are all in the field of Digital image processing in the medical field.
- Restoration and Enhancement-Image restoration and enhancement refer here to methods applied to digital images to make them better presentable for various purposes It includes sharpening, zooming, blurring, etc.
- Pattern Recognition-Pattern Recognition is the study of the contents of a digital image to detect the presence of any pattern or correlation among the pixels based on some statistical features. Pattern recognition is used to implement computer-aided diagnosis, recognize handwriting and recognition of images.
- Remote Sensing-Remote sensing is the acquisition of data without any physical contact. This is widely used in satellite and aircraft for object recognition and classification.

1.2 Biomedical Image Processing

By the increasing use of digital image processing in the medical sector, digital image processing become very important in healthcare. Biomedical imaging mainly focused on the capturing of pictures for each diagnostic and therapeutic functions is a very broad field. X-Ray (CT scan), Ultrasonic Sound, Magnetism (MRI), Nuclear Medicine, Endoscopy, etc. are used for Bio-Medical image processing. We can monitor organ condition or inner tissue condition. Nowadays machines that are used for diagnosis

equipped with digital sensors that give us a more clear and enhanced image. Image reconstruction and modelling techniques permit the instant process of 2D to 3D pictures. When Ct scan was first invented, it took more than 24 hours to construct an image from the signal. But now it takes a few seconds for reconstruction. Depending on the image enhancement, reconstruction, pattern detection doctors or physician can analyze diameter, volume, the vasculature of tumor or organs.[5]

But there are some restrictions in biomedical image processing. There is a gap between bio-medical images and digital image processing. It is difficult to integrate bio-medical images into automatic image processing directly. In bio-medical, there are three main aspects of the gap. [6]

- Medical images mainly consist of organs, tissue, body parts. Even if pictures captured with the same standardization, shape, size, volume structures will change from patients to patients. So it is very difficult to get 100% accuracy by using only one algorithm. [6]
- Extraction of the subject from the background is very difficult in bio-medical images because the object is presented by the entire image. Segmentation is very difficult because shape or borderlines present in images are fuzzy.

Recently, many advanced algorithms show a great potential to analyze and diagnose images accurately and can solve these above problems. Current research work shows promising automated diagnosis by using artificial intelligent techniques and systems. These advanced techniques can extract features from images correctly and physician or doctors can work more efficiently. It not only uses to detect disease correctly but also reduces the burden of physicians. [7]. A typical bio-medical image processing is shown in Fig. 1.2

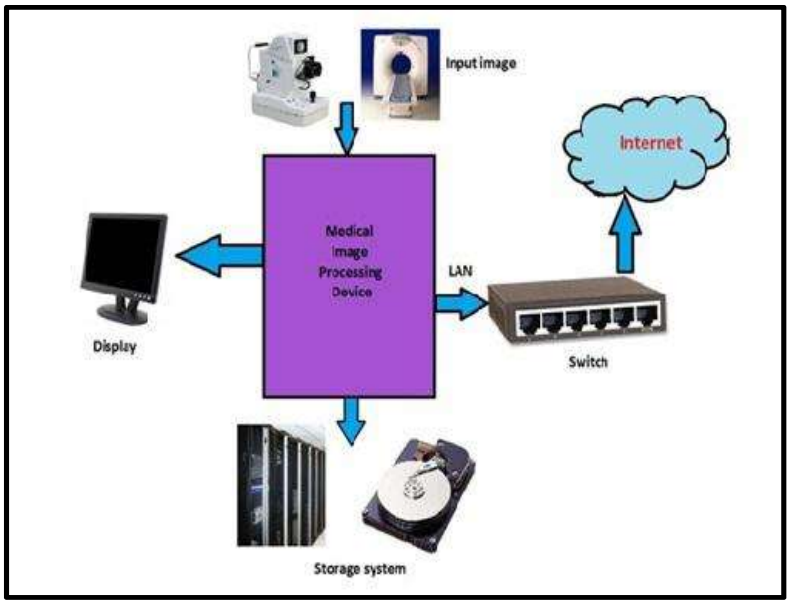


Fig. 1.2 Illustration of a typical biomedical image processing system

1.3 Endoscopy

Endoscopy is a procedure that enables a doctor to look inside a human body[7]. Originally, scrutiny was solely utilized in the muscle system, stomach, and colon. Now, doctors use scrutiny to diagnose diseases of the ear, nose, throat, heart, tract, joints, and abdomen. An endoscope is a long, thin tube with a lens in front of it, as shown in Fig. 1.3.

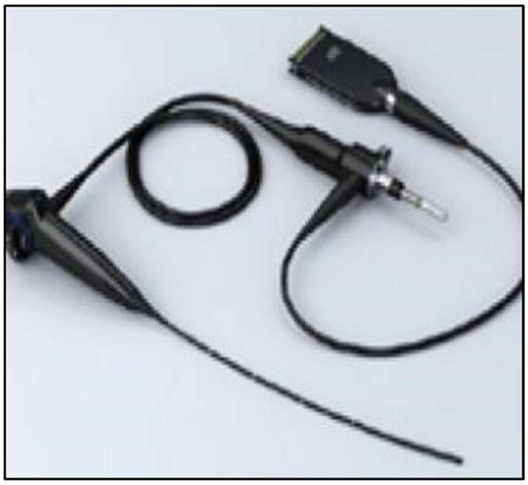


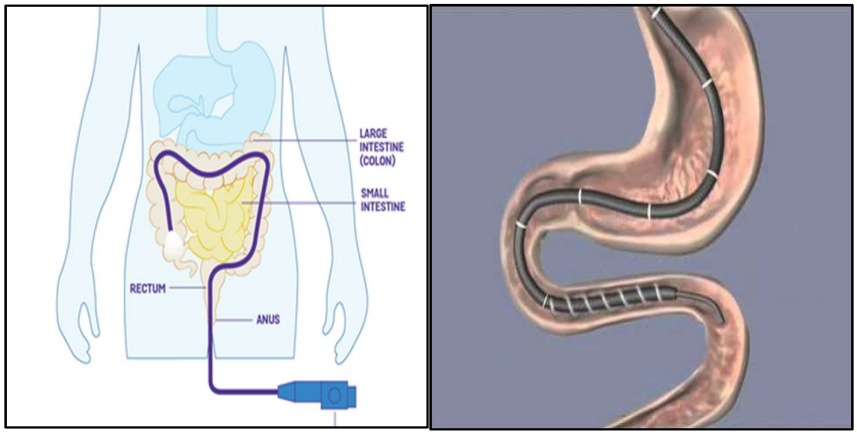
Fig. 1.3. Endoscope

Philip Bozzini created Lichtleiter (light guiding instrument) to observe the human body through a tube in 1805[7].In 1853, Antoine Jean Desormeaux of France developed an instrument specially designed to look at the urinary tract and the bladder. He named it "endoscope," and it had been the primary time this term was employed in history. After a series of trials, Dr. Adolph Kussmaul of Germany succeeded in taking a glance within the abdomen of a living physique for the primary time in 1868. Ten years later, 2 doctors named Max Nitze and Josef Leiter discovered a cystourethroscopy and in 1881, Johann Von Mikulicz and his associates created the primary rigid endoscope for sensible applications. But finally, in 1932 Dr, Rudolph Schindler developed a flexible gastroscope. In 1898 Lange and Meltzing of Germany first took attempted to develop gastroscope with a camera. In 1949, a doctor engaging at the University of Tokyo medical center requested Olympus Optical Co., Ltd. (currently Olympus Corporation) to develop a camera that would photograph and examine of the inside of a patient's abdomen. But there were many difficulties to develop gastroscope with the camera. In 1950, researchers, having had some tremendous ordeals, finally unveiled the primary paradigm. The instrument was equipped with a photographic lens situated at the tip of the flexible tube. Basil Hirschowitz and his associates replaced this endoscope tube with glass fiber in 1960. In 1964 first gastrocamera with fiberscope was invented. In 1976 CCD was used in gastroscopy to convert images into a digital signal to display in a computer monitor. November 2002 saw the disclosing of the world's 1st examination system which supported high-definition television technology, that radically modified the concept of endoscopes.

Endoscopy is used to investigate many areas of the human body which are given below. [8]

- Gastrointestinal tract:
  GI tract includes upper GI tract (Esophagus, stomach, and duodenum) and lower GI tract (small intestine, large intestine, colon, rectum, and anus).as shown in Fig. 1.4.

Enteroscopy – It is a procedure to examine small intestine with endoscopy.
Colonoscopy- Endoscope large intestine.
Rectoscopy- Endoscope rectum.
Anoscopy- endoscope anus.



(a) (b)

Fig. 1.4 (a) Colonoscopy and (b) Upper GI tract endoscopy

- Respiratory tract -

  Rhinoscopy-It is used to examine inside the nose. It consists of a lens and a light source, as shown in Fig. 1.5

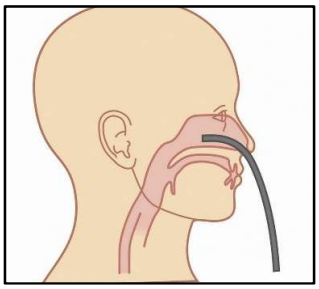


Fig 1.5. Rhinoscopy

- Ear -

  Otoscopy- It is used to examine the ear. as shown in Fig. 1.6.

Fig 1.6 Otoscopy

- Urinary tract -

  Cystoscopy- It is the endoscopy of the urinary tract, as shown in Fig. 1.7.

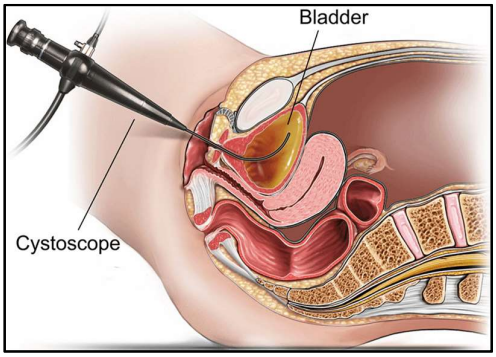


Fig. 1.7 Cystoscopy

- Female Reproductive Tract, Fig. 1.8 -

  The colposcopy-this procedure is used to diagnose Cervix.
  Hysteroscopy-It is the process through which uterus is examined.
  Falloposcopy- Fallopian tube inspection process.

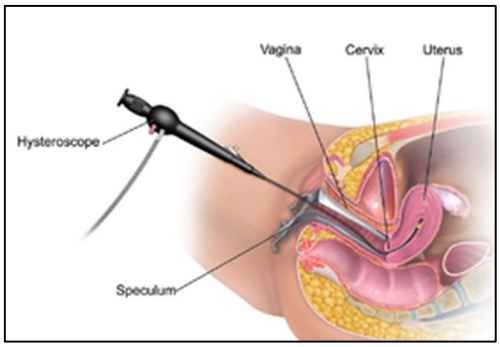


Fig. 1.8 Endoscopy in female reproductive tract

- Through a small incision, Fig. 1.9 -

  Laparoscopy- it is used to examining pelvic cavity.
  Arthroscopy-this procedure is used for insertion of a joint.
  The thoracoscopy-endoscope process used for organs in the chest.

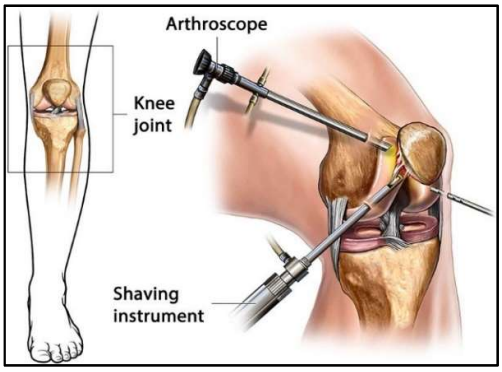


Fig. 1.9 Endoscopy through a small incision

There are mainly two types of endoscopy-

- Traditional endoscopy
- Wireless capsule endoscopy

Traditional Endoscopy:

In traditional endoscopy procedure, the endoscope tube is inserted directly to the digestive tract. It is a flexible tube and consists of a tiny camera on the end of the tube. This camera records images from the inner digestive tract as shown in Fig. 1.10. For upper digestive tract endoscopy, 6-8 hours fasting is required. The colon must be cleared of stools for endoscopy. So laxatives are given to the patients (used for increasing bowel movement). During endoscopy, sedation is provided through injection. It produces relaxation and light sleep.

Though it is a very safe procedure, it has many risks [8]-

1. Bleeding
2. Infection-The risk of infection is very low. But sometimes infection caused by removing a part of the tissue.
3. Sometimes a tear in the GI tract may require surgery to repair it.
4. Reaction to Sedation-Sedation's harmful reactions occur some cases

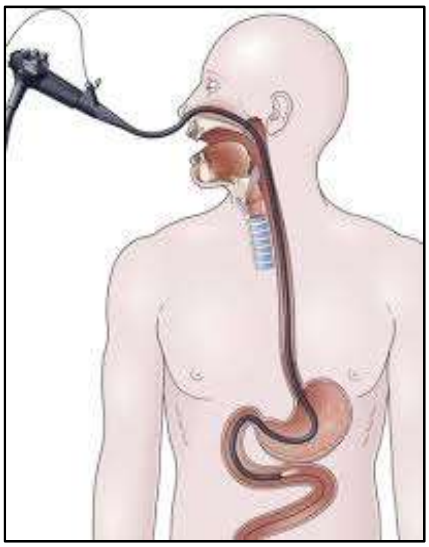


Fig. 1.10 Traditional endoscopy

Wireless Capsule Endoscopy:

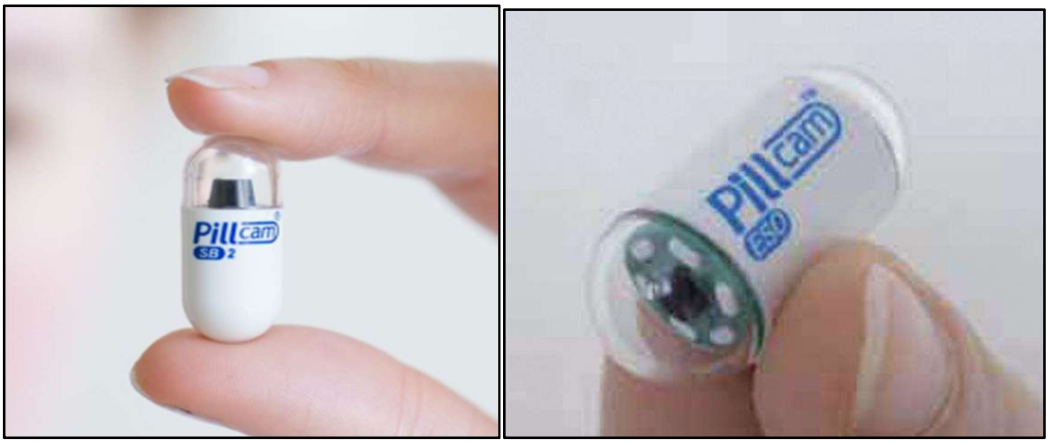
WCE is used to record the inner part of the gastrointestinal tract, as shown in Fig. 1.11.WCE was developed in 1960. Traditional endoscopy is incapable of recording small intestine, which leads to the invention of the Wireless Capsule Endoscope.[9]

WCE is very small in size (11mm x 26mm) and it has one or two small miniature camera. Its battery works for 5-8 hours. It takes photos of lesions of the GI tract at a rate of 2 frames /Sec. It produces 50,000 images for the whole digestive tract for one patient. Then these videos are transmitted to a data recording device which is worn by patients. Video is examined by a physician after completion of this procedure.[9]

Fig. 1.11 Wireless capsule endoscope in GI tract

Many types of capsule endoscopes are found commercially. The first model of capsule endoscope (named as PillCam) was developed by an Israeli Company. In 2001 it is approved in Europe and the United States to detect abnormalities. There are different types of capsule endoscope are available in the market which are mentioned below [9]:

- PillCam SB2 – It is the first generation of Capsule Endoscopy which is developed in 2001 and its 2nd generation was developed in 2007, as shown in Fig. 1.12(a)
- PillCam ESO3, as shown in Fig. 1.12(b) – First generation was developed in 2004.
  Second generation was developed in2007.
  Third generation was developed in 2011.
- PillCam Colon 2, as shown in Fig. 1.12(c) – First generation was released in 2006.
  Second generation was released in 2009.
- MiRoCam, as shown in Fig. 1.12(d) –It was developed by Intelligent Micro System Centre (Seoul, Korea).
  First generation was released in 2006.
  Second generation was released in 2011.
- OMOM, as shown in Fig. 1.12(e) – It is developed by Jinshan Science and Technology Company(China).
- EndoCapsule, as shown in Fig. 1.12(f)– It is developed by Olympus in 2006.
- Sayaka, as shown in Fig. 1.12(g)– It is developed by RF System Lab in 2005.



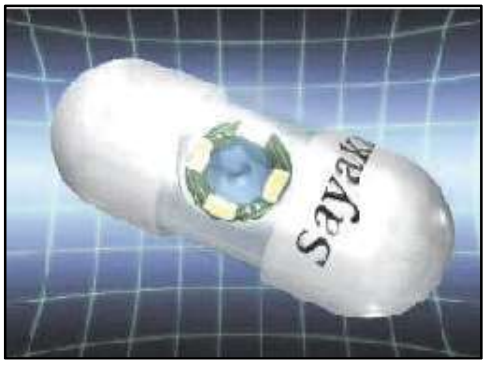
(a) (b)

(c)

(d)

(e)

(f)



(g)

Fig. 1.12 (a) PillCam SB2 (b) PillCam ESO (c) PillCam Colon2 (d) MiroCam (e) OMOM (f) EndoCapsule (g) Sayaka

Table 1.1 Commercially Available Capsule Endoscope and Comparison:

	PillCam SB2	PillCam ESO3	PillCam Colon2	MiRo-Cam	OMOM	Endo-Capsule	Sayaka
Dimension (mm)	26x11	26x11	32x11.6	24x10.6	27.9x11	26x11	31x11.3
Weight(g)	3.4	3.7	2.9	3.3	6	3.8	10
Field of view(o)	156	169	172	175	140	160	75
Cameras	1xCMOS	2xCMOS	2xCMOS	1xCMOS	1xCCD	1xCCD	1xCCD
Frame/second	2	35	4 to 35	1 to 3	0.5 to 2	2	30
Communication	RF	RF	RF	HBC	RF	RF	RF
Battery life(h)	9	0.3	10	13	8	12	Unlimited
Country	Israel	Israel	Israel	South Korea	China	Japan	Japan
Receiver Antennas	8	3	8	11	14	8	Na
Capsule cost	37,100 rupees	40,000 rupees	38,425 rupees	26,500 rupees	26,500 rupees	40,000 rupees	30,000-40,000 rupees

Table 1.2 Advantages and Disadvantages of Endoscopy and Wireless Capsule Endoscopy

Types of Endoscopy	Advantages	Disadvantages
Traditional Endoscopy	• Low cost • Less time require.	• Though it is a very safe process sometimes patients face some side effects. • high power consumption • couldn't visualize all part of the gastrointestinal tract. • It is not portable. The units must be plugged into power outlets.

		• It takes more spaces than equivalent wireless technology. Wires, cables, desktop take a lot of spaces than wireless capsule endoscope.
Wireless Capsule Endoscopy	• Small in size and easy to swallow • Higher rate of communication • Low power consumption • No side effects.	• Cost is higher than a traditional endoscope. • It takes 8-12 hours to travel through the GI tract.

1.4 Polyps

A polyp is an abnormal growth of tissue on a mucous membrane[10]. Polyps unremarkably grow within the colon or intestines, however, they will conjointly develop within the abdomen, ears, vagina, and throat.The main concern is the malignant transformation of polyps. So polyps are the main cause of colon cancer.[10]

Colorectal cancers are the greatest threat to humanity. According to the statistics of the Centre for Health Protection, Hong Kong, colorectal cancer is the second common cancer and is considered as 16.6% of all cancer cases (in 2010). It is 2nd most common death in the US. Colorectal cancer is the third most common disease in men and the second most common disease in women.1.8 million colon cancer was found in 2018[11]. India has a lower rate of colon cancer than the Western world. But in 2018 death rate by colon cancer is 19,548[11]. Polyps are the first stage of cancer. But all polyps are not cancerous. It takes many years to turn into cancer. So early detection can prevent colon cancer. From the case study, we came to know that 11% of all patients are detected polyps and found in 14.7% of patients over the age 40 of which 41.8% were adenomatous polyps. Polyps were found in 2.3% of patients in the age below 30 years and 5.8% in the age of 30-40 years. Therefore, polyp's segmentation or detection is very important. There are several automated methods for polyp segmentation and detection.5 years survival rate for colorectal cancer is shown in Fig. 1.13.

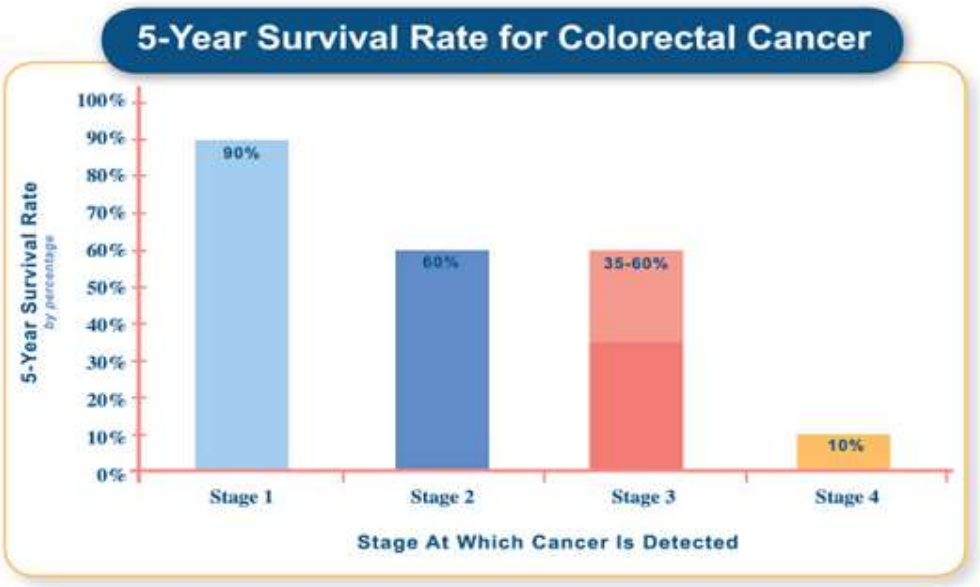


Fig. 1.13 5- year survival rate for colorectal cancer

Different Types of Polyps, as shown in Fig. 1.14 and Fig. 1.15

- Sessile polyps -
  It grows flat on the tissue lining the organ. It has a mushroom-like structure and has a cap with no stalk. Sessile polyps can be removed during colonoscopy or surgery.[12]
- Pedunculated Polyps -
  It rises like a mushroom-like structure and has a cap with a thin stalk.
- Adenomatous Polyps -
  Its structure is flat or slightly depressed. It is most common in people.
- Adenocarcinoma polyps -
  When adenomatous polyps become malignant, it is called adenocarcinoma polyps.

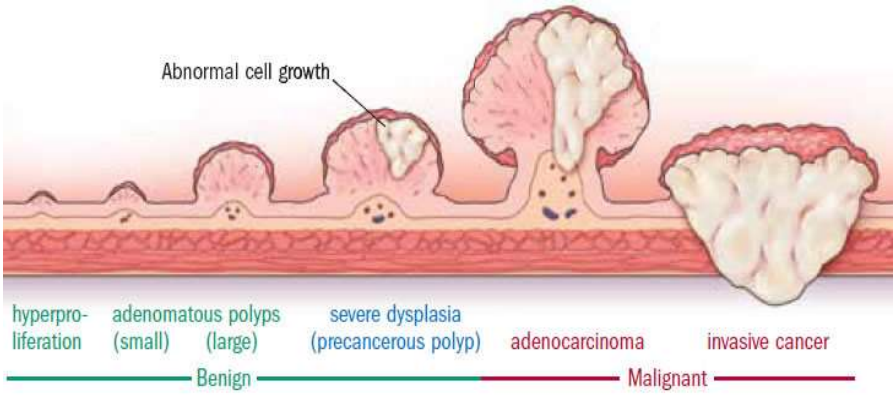


Fig. 1.14 Different types of polyps

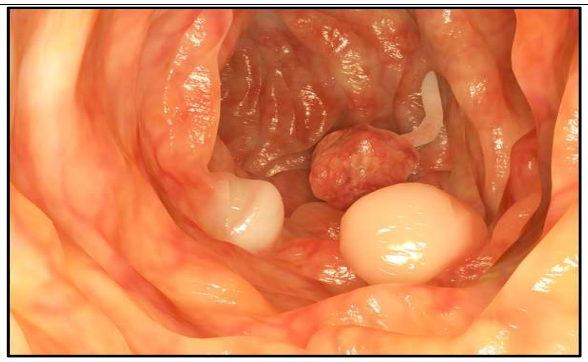
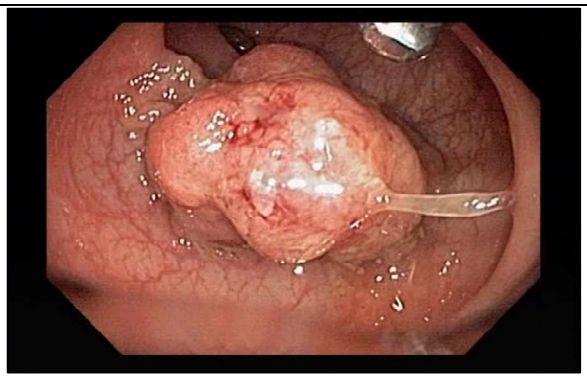
Different types of polyps	Polyps images
Sessile Polyps	
Pedunculated Polyps	
Adenomatous Polyps	
Adenocarcinoma polyps	

Fig. 1.15 Different types of polyps in GI tract

Causes of the Polyps -

- Polyps are formed by dividing cells even when new cells are not needed. Polyps can form anywhere in the large intestine. Polyps are divided into two groups on the basis of malignancy. These are-Non-neoplastic and Neoplastic[12]

  Non-neoplastic- These are non-cancerous polyps. Hyperplastic Polyps, inflammatory Polyps, and Hamartomatous Polyps are falls in this group.

  Neoplastic –These are becoming cancerous. These are the largest in size. Adenomatous polyps are fall in this group.

  In general, we can conclude that larger in size greater risk of cancer.

- Heredity is one of the main cause of polyps.
- Food habit also causes of polyps.
- Overweight.
- Infection.

Symptoms of Polyp:

Generally, colorectal polyps have no symptoms. But some people experience several symptoms of polyps. Like- rectal bleeding, blood may be showed up in stool and that causes a change of stool color, constipation or diarrhea may last for a week, bleeding from polyp region can cause anemia. [12].

1.5 Aim of This Thesis

Once the capsule is swallowed by the patient, cameras start capturing and recording images. It generates normally 55,000 to 80,000 images for a patient. After 8 hours of examination, the physician downloads the data from the receiver and started to examine. So it very time-consuming process for a physician or doctor to find out polyps from 55,000-80,000 images.It is also very difficult task for doctors using traditional endoscopy. So polyp segmentation is a very important task. Computer-aided polyp detection reduces time,complexcity and increases accuracy.

In this thesis,the main concern is to create an algorithm to segment out polyp regions from endoscopy images. In this process, R-channel is extracted from RGB polyp images. After that thresholding is done by a fixed value. Then the largest connected area is detected. Some morphological operations are performed to remove small regions.

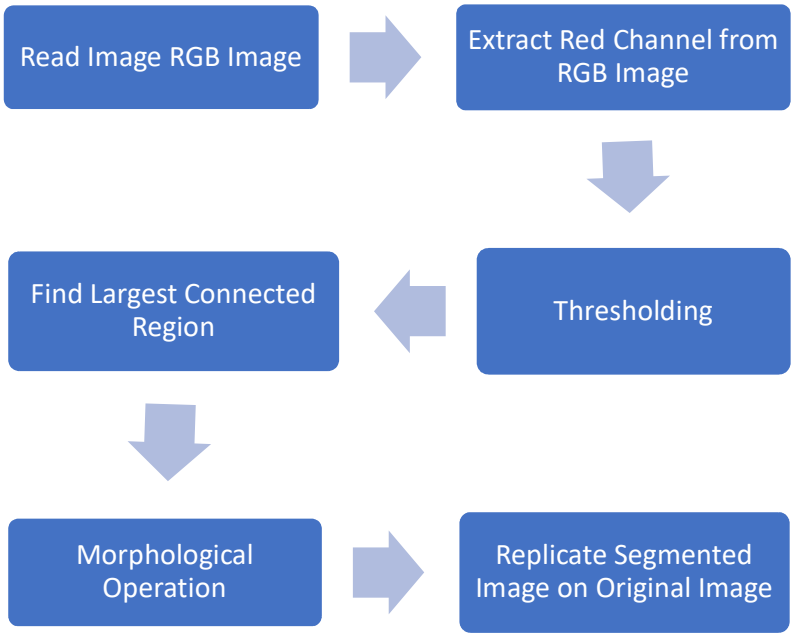


Fig. 1.16 Flow chat of the proposed algorithm

CHAPTER 2

CHAPTER 2

Literature Survey

Colorectal cancer is the third most common disease in men and the second most common disease in women.1.8 million colon cancer was found in 2018[11]. As discussed earlier in the polyp section India has a lower rate of colon cancer than the Western world. But in 2018 death rate by colon cancer is 19,548[11]. Polyps are the first stage of cancer. But all polyps are not cancerous. It takes many years to turn into cancer. So early detection can prevent colon cancer. Therefore, polyps' segmentation or detection is very important. There are several automated methods for polyp segmentation and detection.

The authors [13] are proposed opponent color feature integrating with LLE –based Local binary pattern texture features to distinguish the polyp images from the normal images by using SVM classifier. The authors in [14] used local fractal dimension features over SIFT key points. After that these features are concatenated with the uniform local binary pattern. Then various classifiers are used to classify normal polyps. Finally, the combined features are fed to SVM, MLP and random forest for recognition phase. In [15] authors applied SVM to identify different types of polyps. Since there are two different types of polyps, namely hyperplasia, and adenomas. Hyperplasia is a benign polyp and does not have a chance to change into cancer. But adenomas polyps turn into cancerous polyps. The authors mainly focused on the feature extraction process. The authors in [16] used data sampling based boosting framework to learn different types of polyps. The authors in [17] mainly focused on identifying cancerous and noncancerous polyps. In the first step, they used a region-based active contour method where Gaussian filter is used and the second step they applied geometric shape for features. In paper [18] authors used water segmentation method for segmenting polyp region because this method can handle broken edge properties. The authors in [19] used two steps for the segmentation process. The first step they used K-means clustering for segmentation which is mainly based on pixel values and colors. The second step is based on localization based active contour region. In paper [20] authors used steps for segmentation and classify polyp region. Superpixel method is applied to the frames of images. After that, they extract 164 features and finally classify polyps by SVM method. The authors in [21] proposed an automated method for polyp detection. First, they labeled polyp and non-polyp frames using geometric shape and texture. The authors in [22] used two segmentation methods. The first method is a linear thresholding method to detect saturated region from HSV (hue saturation value) plane images. The second method is the Markovian Random Field. After segmenting images SVM classifier is used to classify. In paper [23] authors used 2D and 3D data to identify polyps and also identify it is cancerous or not. The first step is based on polyp detection from 2D images using textural and geometrical features. The second step is the classification of cancerous and non-cancerous polyps. The authors in [24] integrated 22 Haralick features with SIFT features. Then they used a neural network as a classifier. The authors in [25] identify different types of polyps using curvature.

CHAPTER 3

CHAPTER 3

SEGMENTATION

Image segmentation is the process of partitioning an image into small multiple segments. In the segmentation process, we can simplify images to analyze easily. Segmentation should stop when we found ROI. It can be said that it is the first step of any automated computer vision application[1]. Different types of segmentation process are shown in Fig. 3.1. There are many applications of segmentation process- Computer vision, medical imaging(Tumours identification, tissue volumes measurements, diagnosis of abnormal structures in the human body, surgery planning in critical condition), object detection, face recognition, fingerprint recognition, iris recognition, navigation. Image segmentation is generally based on basic properties of intensity values of an image. An accurate segmentation method is very challenging.[26]

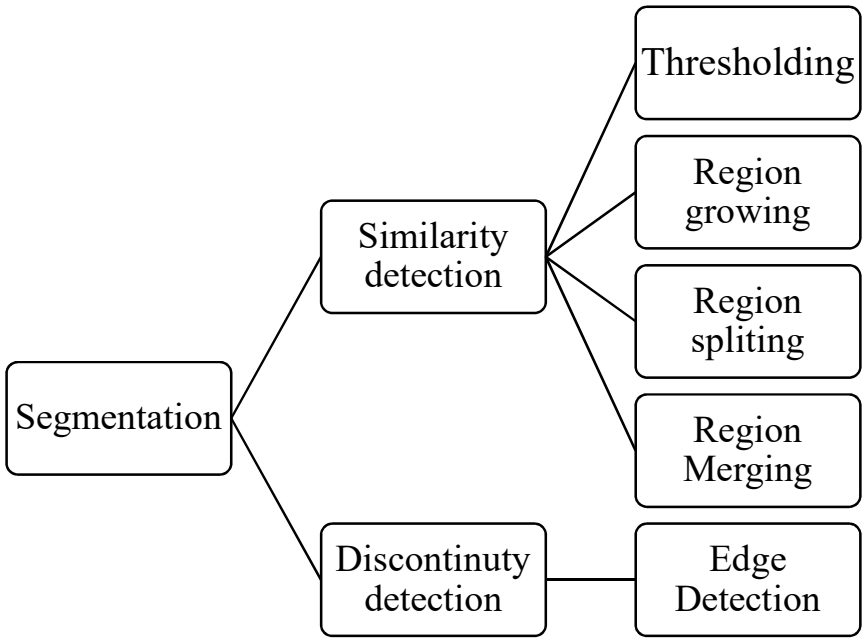


Fig. 3.1 Types of segmentation

Medical Image Segmentation is the method of automatic or semi-automatic detection of boundaries from 2D or 3D images[27]. A major issue of medical image segmentation is the high variability in medical pictures. First and foremost, human anatomy shows major modes of variation. Furthermore

different modalities (X-ray, CT, MRI, Microscopy, PET, SPECT, Endoscopy, OCT, etc) are used to create medical images. The result of the segmentation can be used to obtain further diagnostic process. Possible applications are automatic cell detection, disease detection, cell counting, etc.

3.1 R Channel Extraction from RGB Colour Space

The partially psychological way in which human cognition formulates colour imagery based on wavelength is not something that can be duplicated in a machine. Machines use a colour model, which can be described as a mathematical approximation of the inherently nonquantifiable nature of human visual perception. Many colour models exist, and presumably, they all have advantages and disadvantages that make them more or less suitable for a given application. In this thesis, the use of RGB colour model is discussed as the proposed segmentation process is oriented on this particular colour model.

The RGB colour model is a colour model in which red, green and blue light are added together in various ways to reproduce a broad array of colours. The name of the model comes from the initials of the three primary colours, red, green, and blue. The main purpose of the RGB colour model is for representation and display of images in electronic systems. RGB channels follow the colour receptors in the human eye, and are used in computer displays and image scanners. The RGB image is 24-bit (the industry standard as of 2005). Each channel has 8 bits, for red, green, and blue—in other words, the image is composed of three colour channel images where each image can store discrete pixels with conventional brightness intensities between 0 and 255.Shown in Fig. 3.4 .So the total value of pixels is 2^8 =256.

$I_{RGB} = (I_R , I_G , I_B)$ ……..(1)

Where I_R is the intensity of pixel value in the R channel, I_G intensity of pixel value in G channel,I_B intensity of the pixel value in B channel. The range of intensity is also known as colour depth.

Red colour decimal code is (255,0,0), Green colour decimal code is (0,255,0), Blue colour decimal code is (0,0,255). All 3 colour channels have a value 0, it means that it is a black colour region. All three colours channels are set to a maximum value (255). It means that the resulting colour is white.[1]

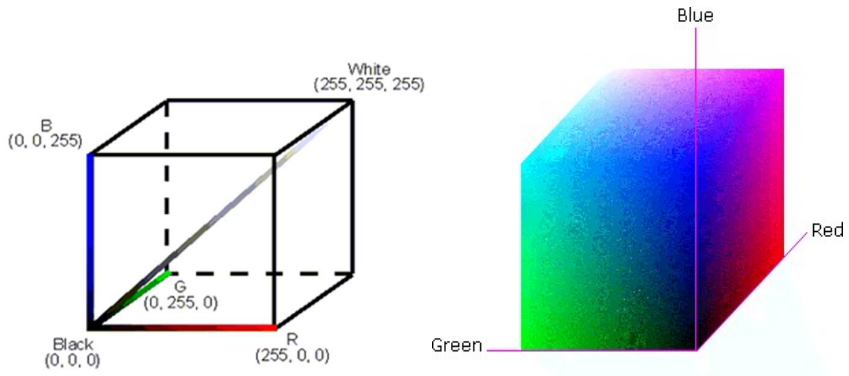


Fig. 3.2 RGB colour space

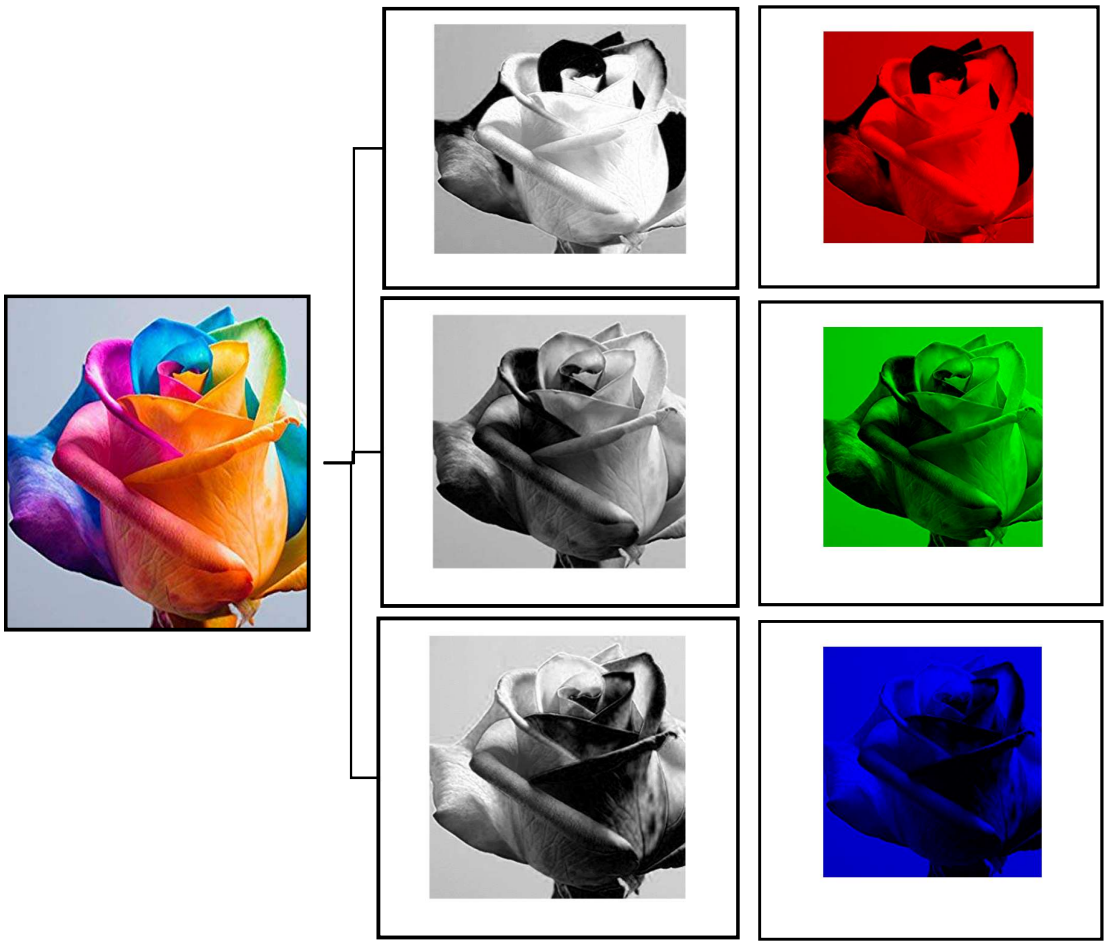


Fig 3.3 RGB image and it's red, green, blue channel images

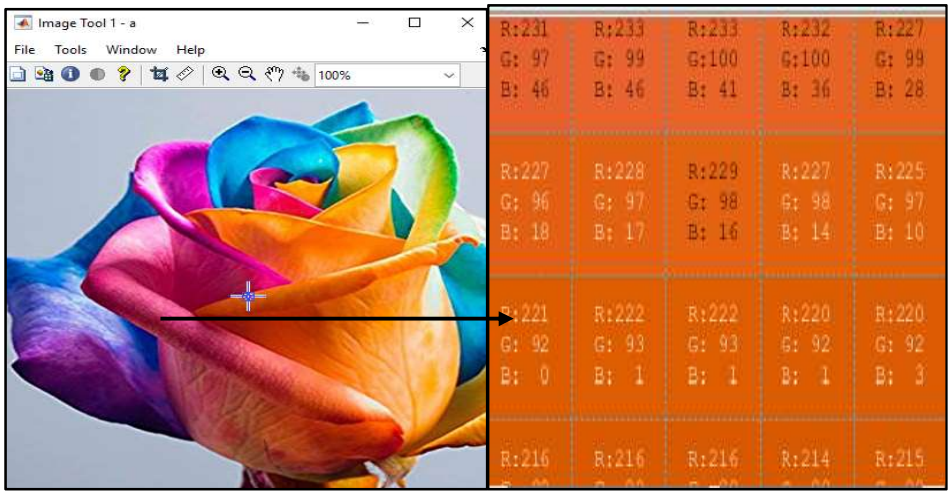
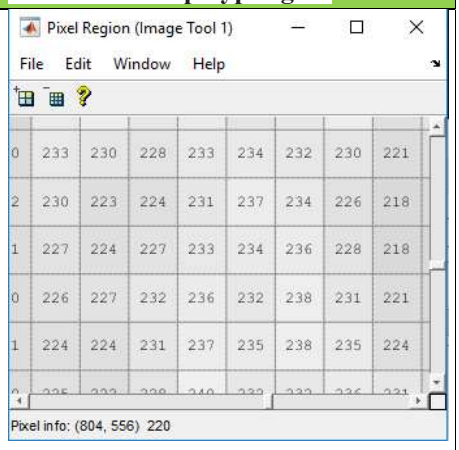
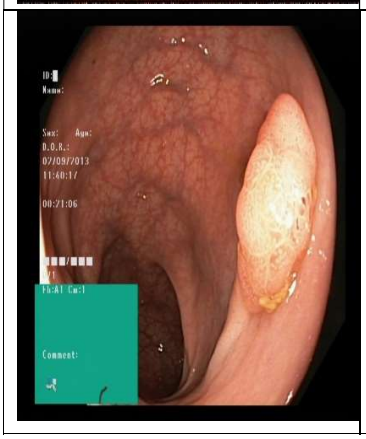
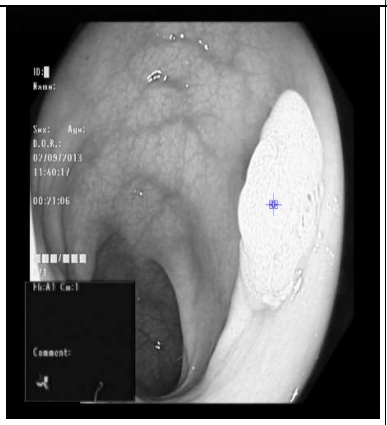
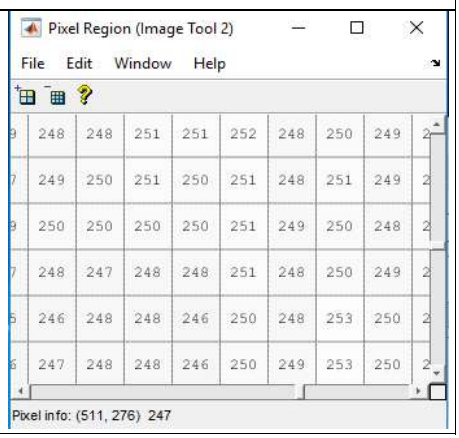


Fig. 3.4 RGB image pixel values

Notice that each separated colour plane in the figure contains an area of white. The white correlate with the highest values (purest shades) of each separate colour. For example, in the Red Channel image, the white represents the highest concentration of pure red values. As red becomes mixed with green or blue, grey pixels appear. The black region in the image contains pixel values that contains no red values, i.e., R = 0.

As discussed in the polyp section a typical polyp consists of colour features corresponding to a red colour as polyps have more vascular pattern than surrounding lesions[28] So a better view of polyps colour features can be obtained through red pixel intensity and for that considering the R channel of RGB colour model is an ideal one. Splitting the RGB image into individual R, G and B channel it can be thoroughly observed that each channel consists of the pixel intensity value of respective component i.e. R, G and B. Fig. 3.3

Now considering the R channel of the input RGB image, it can be observed that the pixel intensity value of polyp region shares similar values within a concentrated region. And it is also observed that few pixel values of non-polyp regions get similar to polyp region but in a discrete manner. Taking advantage of this situation a thresholding method is applied on the R channel of the input RGB image.

Polyp images	R channel images	Pixel values of polyp region
		
		

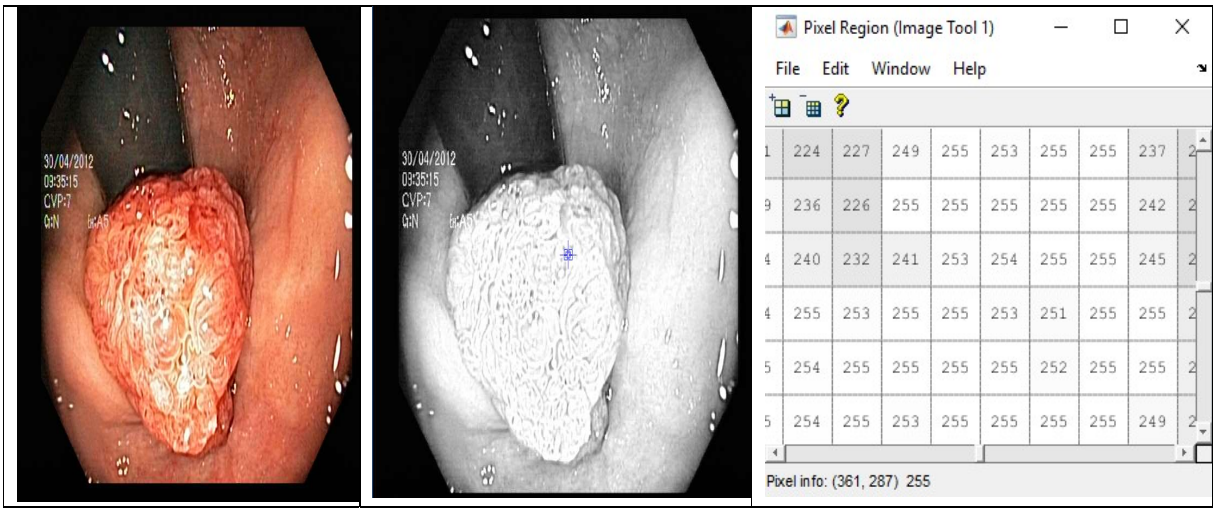


Fig. 3.5 R channel polyps images and its pixel values

3.2 Thresholding

It is the simplest and most effective method of segmentation. Images are converted to binary from grayscale by thresholding method to separate objects from the background. Thresholding can replace pixel values by white and black by using fixed threshold value T.Image pixels are replaced with black pixels if the intensity of a pixel $I_{x,y}$ is less than T and replaced by white pixels if the intensity of pixel $I_{x,y}$ is greater than T.The former and latter region usually labeled with 0 and 1. The segmentation process depends on image property being thresholded and on how the threshold is chosen. The common image property to the threshold is pixel grey level.[26]

g (x, y) = 0 if f (x, y) < T and g (x, y) = 1 if f (x, y) ≥ T, where T is the threshold.

Using two threshold values, T_1, T_2, grey level range related to region 1 can be defined: g (x, y) = 0 if f (x, y) < T_1 or f (x, y) > T_2 and g (x, y) = 1 if $T_1 \leq$ f (x, y) $\leq T_2$. An approach to thresholding is based on the assumption that images are multimodal. Different objects of interest relate to distinct peaks of the 1D signal histogram. The thresholds have to optimally separate those peaks in spite of typical overlaps between the signal ranges corresponding to individual peaks. The threshold in the valley between two peaks that are overlapping separates their main bodies but inevitably detects or rejects falsely some pixels with intermediate signals. The optimal threshold that minimizes the expected numbers of false detections and rejections may not coincide with the lowest point in the valley between two overlapping peaks.

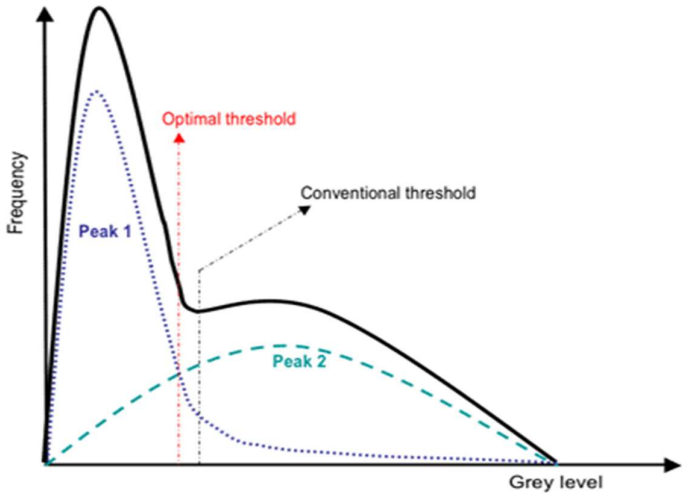


Fig. 3.6 Tholding Using Histogram

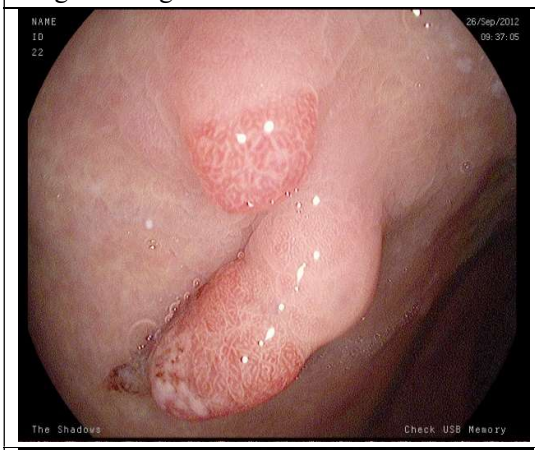
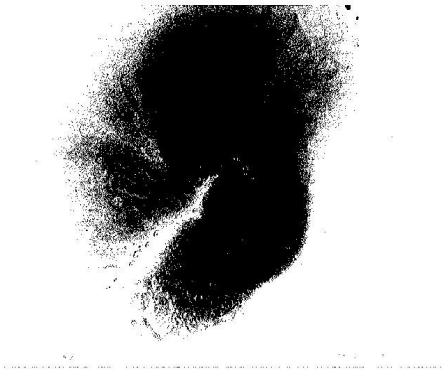
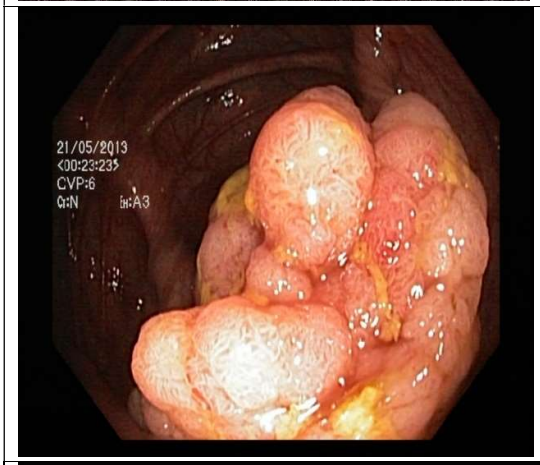
There are many types of thresholding which are discussed below. Since the threshold separates the background from the object, the adaptive separation may take account of probability distributions of object (e.g. dark) and background (bright) pixels. Such a threshold has to equalize two kinds of expected errors by assigning a background pixel to the object and assigning an object pixel to the background. More complex adaptive thresholding techniques use a spatially varying threshold to compensate and it is for local spatial context effects. A simple iterative adaptation of the threshold is based on successive removal of the estimated peak positions. Threshold assumes that- (i) each peak coincides with the mean grey level for all pixels that relate to that peak and (ii) the pixel probability decreases uniformly on the absolute difference between the pixel and peak values both for an object and background peak. The classification of the object and background pixels is done at each iteration j by using the threshold T_j found at the previous iteration. Thus, at iteration j, each grey level f(x, y) is assigned first to the object or background class (region) if $f(x,y) \leq T_j$ or $f(x,y) > T_j$, respectively. Then, the new threshold, $T_j+1 = 0.5(\mu_{j,ob} + \mu_{j,bg})$ where $\mu_{j,ob}$ and $\mu_{j,bg}$ denote the mean grey level at iteration j for the found object and background pixels. Another type of thresholding method is colour thresholding. It may be more accurate thresholding method because more information stored is in colour pixels than grey pixels. Many colour spaces are created for more stable and accurate segmentation. One of the simplest approach is based on some reference colour (R_0, G_0, B_0) and thresholding of Cartesian distances to it from every pixel colour f(x,y) = (R(x,y),G(x,y),B(x,y)).

$$g(x,y) = \begin{cases} 1 & \text{if } d(x,y) \leq d_{max} \\ 0 & \text{if } d(x,y) > d_{max} \end{cases}; \quad d(x,y) = \sqrt{(R(x,y) - R_0)^2 + (G(x,y) - G_0)^2 + (B(x,y) - B_0)^2}$$

……..(2)

where g(x, y) is the binary region after thresholding.

It has been thoroughly observed that the pixel intensity of polyp regions lies within 200-255 and non-polyp region 100-180, so by thresholding pixel intensity with less than 200 are replaced with white and pixel intensity with greater than 200 are replaced with black.

Original Image	Images after Thresholding
	
	
	

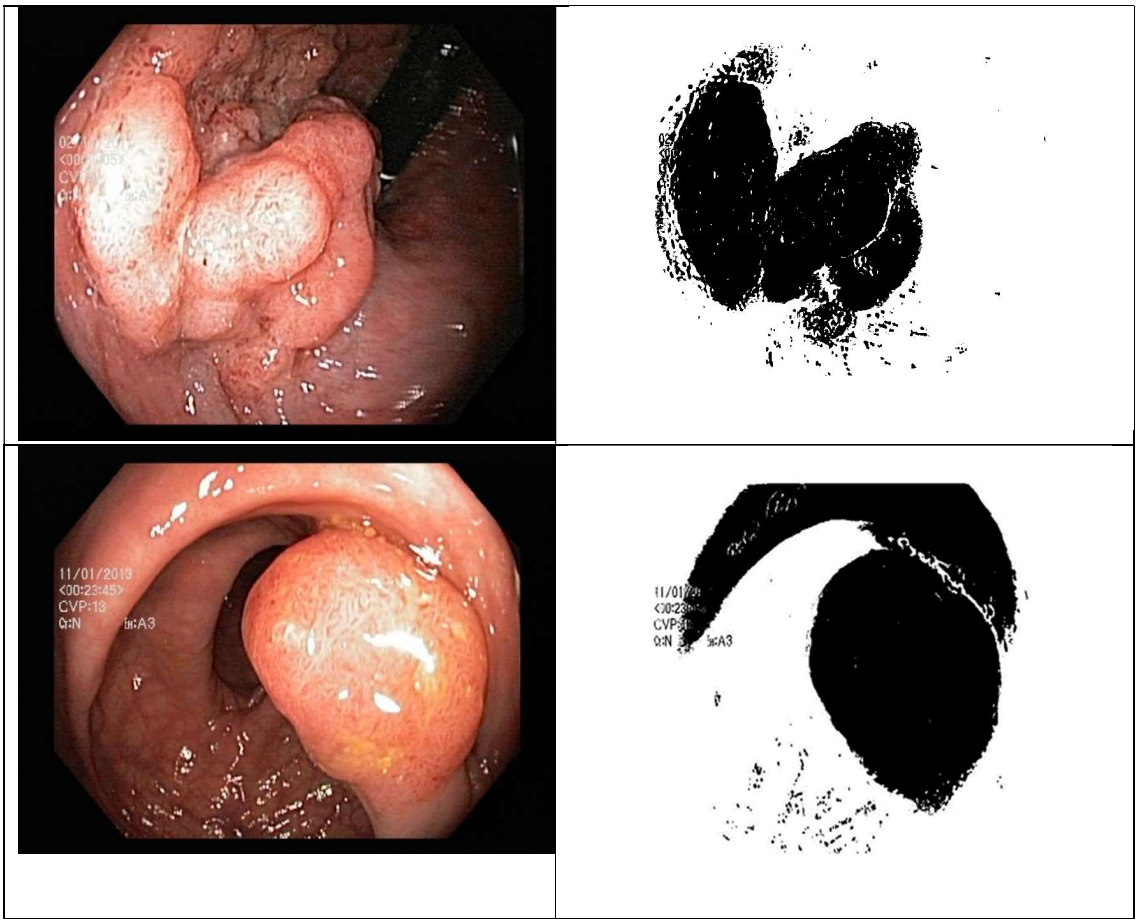


Fig. 3.7 Polyps images after thresholding

3.3 Pixel Connectivity

After thresholding it is noticed that pixel intensity values less than 200 depict white regions whereas pixel values greater than 200 depicts the black region, forming a binary image. The obtained binary image depicts the unwanted regions as white (background) and region with polyps as black (foreground). To segment out only the polyp region from other foreground region, the concept of connectivity is introduced in this section.

Connectivity array-

A connectivity array is defined as the array of pixels values which can be used to find connected components among its neighboring pixels in a binary image. The connectivity array is created solely depending on the type of neighborhood connectivity and a number of dimensions. The connectivity array returns a 3-by-3 logical array. In general type of neighborhood connectivity array are of two types i.e. 'minimal' and 'maximal'. Minimal denotes a neighborhood whose neighbors are touching the central element on an (N-1)-dimensional surface, for the N-dimensional case. Maximal defines a neighborhood including neighbors that touch the central element in any way. [29]

A 2D connectivity array with minimal connectivity looks like

0 1 0

1 1 1

0 1 0

A 2D connectivity array with maximal connectivity looks like

1 1 1

1 1 1

1 1 1

A 3D connectivity array with minimal connectivity looks like

(:,:,1) =

0 0 0

0 1 0

0 0 0

(:,:,2) =

0 1 0

1 1 1

0 1 0

(:,:,3) =

0 0 0

0 1 0

0 0 0

In this thesis, a maximal connectivity array of 2 dimensions is created, which helps in finding the connected components in the obtained threshold image through its connectivity properties. Connectivity is defined by, pixels connected to other pixels. A set of pixels in a binary image that from a connected group is known as a connected component.

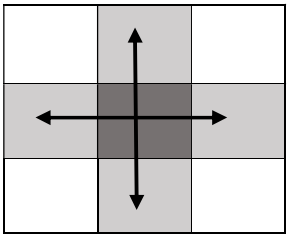
Connected components-

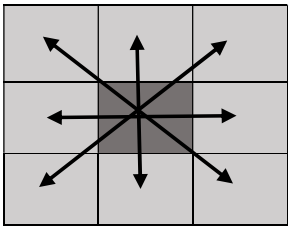
As mentioned above connected components are defined as sets of pixels in a binary image that form a connected group. Determining which pixels create a connected component depends solely on how pixel connectivity is defined. For example, the binary image in Fig. 3.8 contains one foreground object or two, depending on the connectivity. If we consider 4-connectivity then the image is all one object, there is no distinction between a foreground object and the background. However, if the foreground is 8-connected, the pixels set to 1 connect to form a closed loop hence the image has two separate objects: the pixels in the loop and the pixels outside the loop.

0	0	0	0	0	0	0	0
0	1	1	1	1	1	0	0
0	1	0	0	0	1	0	0
0	1	0	0	0	1	0	0
0	1	0	0	0	1	0	0
0	1	1	1	1	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

Fig. 3.8 Pictorial representation of the connected component

Table 3.1 Lists of the Standard Two-dimensional Connectivity

Types	Definition
4-connectivity	Two adjoining pixels are connected along the horizontal or vertical direction, it is called 4-connectivity. 

8-connectivity	8-connectivity means pixels are connected along the horizontal, vertical and diagonal direction. by different measurements of each region as they are specified by the properties. 

In this proposed method 2 dimensional, 8-connectivity is used to find the connected components in the obtained binary image. Next, the connected component achieved is extracted from the binary image using the area attribute.

It is observed from the binary image that a polyp can be distinguished as a solid surface structure and to express the quantity of any solid surface structure, the area is used. So extracting the connected components with respect to area attribute give a solid hold on the proposed segmentation method. The results of the extracted connected component on the obtained threshold image are shown in the fig 3.10 below.

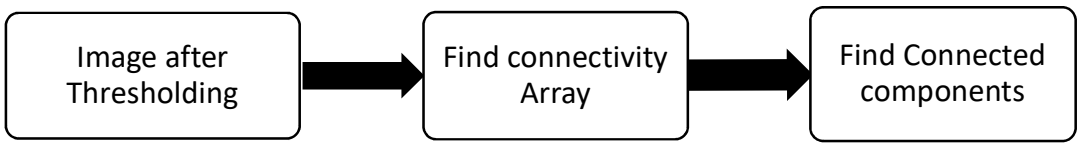
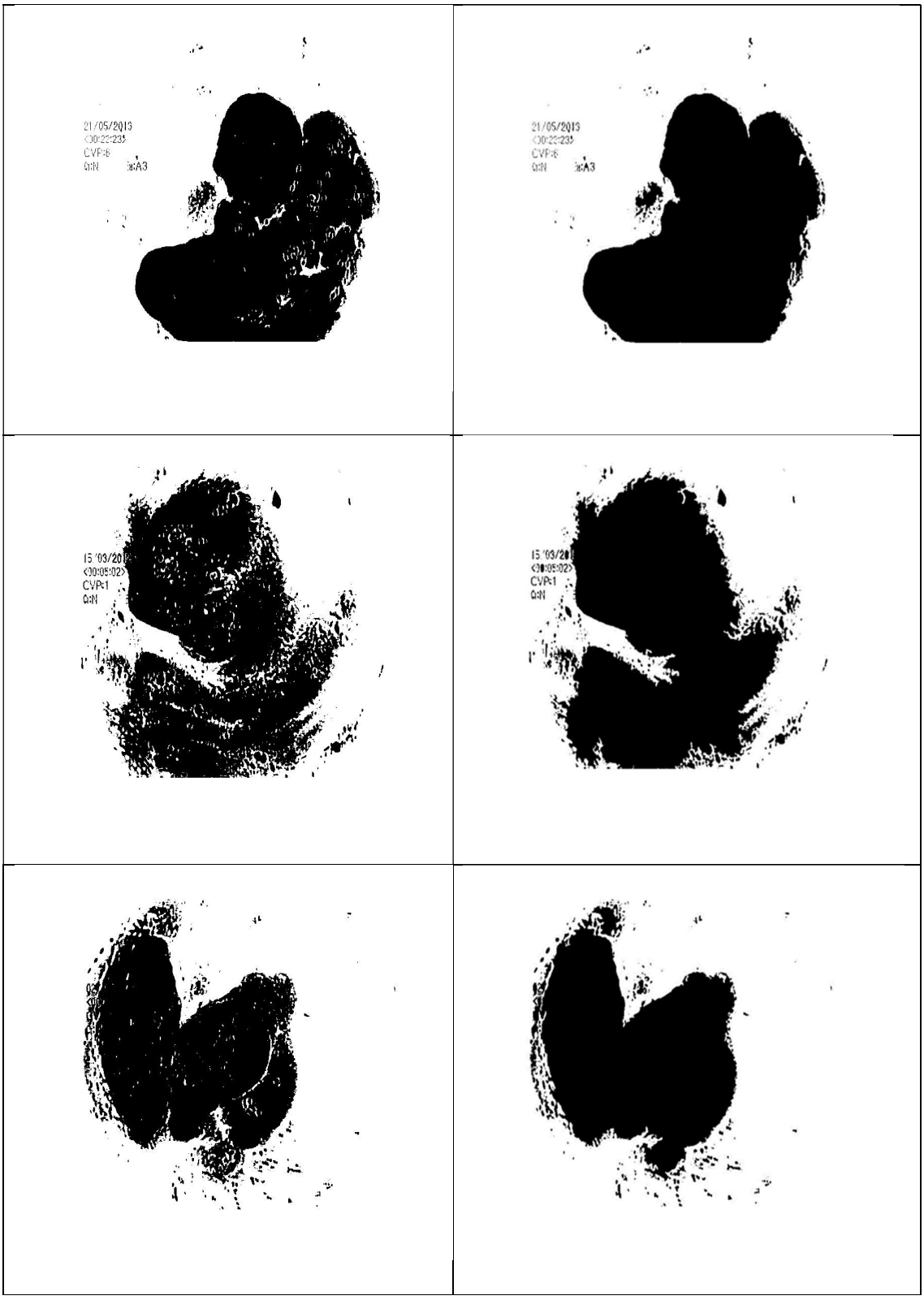


Fig. 3.9 Flow chart of finding connected component process

Image After Thresholding	Connected component
	


21/05/2013
CVP:6
21/05/2013
CVP:6
CVP:1
CVP:1

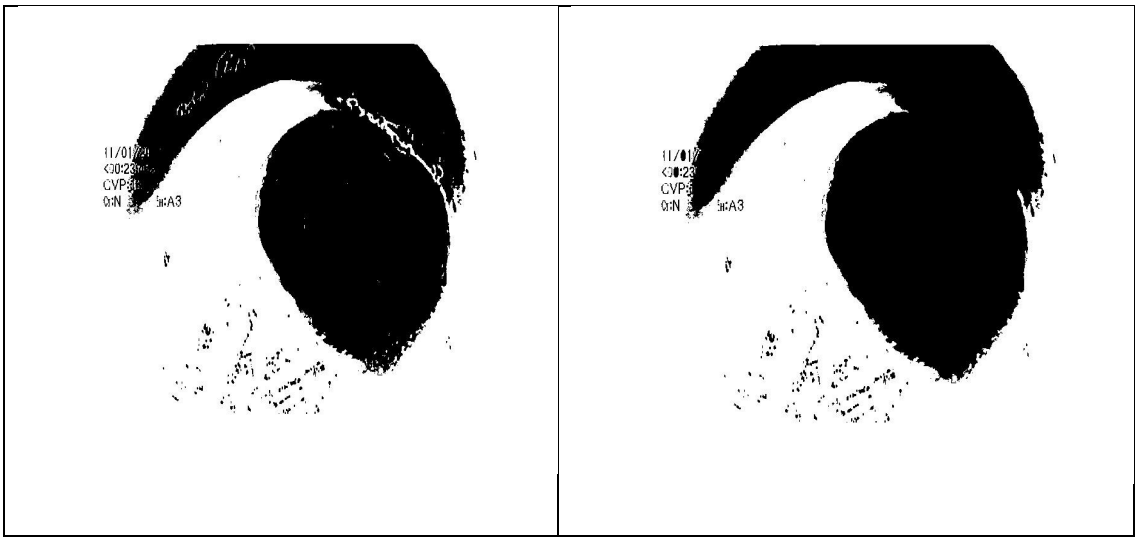


Fig. 3.10 Pictorial representation of polyp images after find connectivity

3.4 MORPHOLOGICAL OPERATION

Morphological image processing is a collection of non-linear operations which is related to the shape or morphology in an image. [30]

Morphological operations depend only on the relative ordering of pixel values and do not depend on their numerical values. Therefore morphological operations are especially suited to the processing of binary images. It can also be applied to greyscale images such that their light transfer functions are unknown and therefore their absolute pixel values are of minor interest. Morphological techniques divide an image into a small shape or template called a structuring element. The structuring element is placed at all possible locations in the image, as shown in Fig. 3.11. Then it is compared with the corresponding neighborhood of pixels. Some operations test whether it fits with the neighborhood while others test overlapping with the neighborhood.

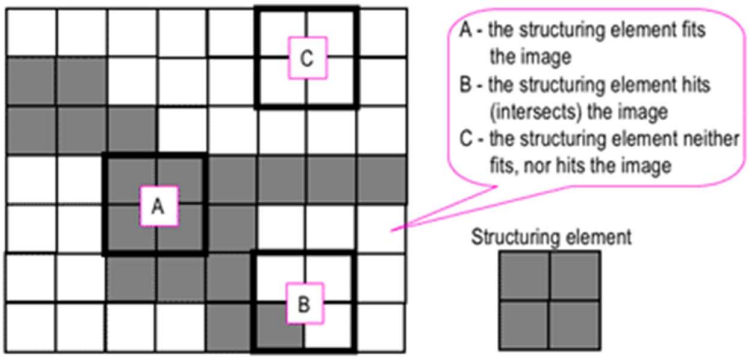
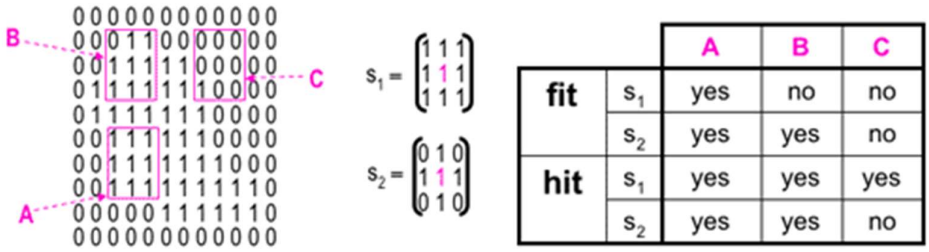


Fig. 3.11 Morphological operation and structuring element

Morphological operations which test binary images create a new binary image if the test is successful. The structural element of a morphological operation is a small binary image. The patterns of zeros and ones represent the structural element. A structuring element is placed in a binary image, each of its pixels is associated with the corresponding pixel of the neighborhood under the structuring element. The structuring element is said to fit the image if, for each of its pixels set to 1, the corresponding image pixel is also 1. A structuring element is said to hit, an image if, at least for one of its pixels set to 1 the corresponding image pixel is also 1, as shown in Fig. 3.12.



		A	B	C
fit	s_1	yes	no	no
	s_2	yes	yes	no
hit	s_1	yes	yes	yes
	s_2	yes	yes	no

Fig. 3.12 Structuring element

Erosion and dilation are two fundamental morphological operations. The erosion of a binary image *f* by a structuring element s (denoted $f \ominus s$) creates a new binary image ,which is denoted by $g = f \ominus s$ with ones in all locations (x, y) of a structuring element's origin at which that structuring element s fits the input image *f*, i.e. g (x, y) = 1 is s fits f and otherwise it is 0. Erosion removes pixels from the boundary. Dilation is the opposite of erosion. Dilation of an image *f* by a structuring element s produces a new binary image $g = f \oplus s$ with ones in all locations (x,y) of a structuring element's origin. The structuring element s hits the input image *f*, i.e. g(x,y) = 1 if s hits f and otherwise it is 0, repeating for all pixel coordinates (x,y). Dilation is opposite of erosion. It adds pixels to both the inner and outer boundaries of regions. f^c is the complement of an image *f*, i.e., the image produced by replacing 1 with 0 and vice versa. Formally, the duality is written as

$$f \oplus s = f^c \ominus s_{rot} \quad \ldots\ldots(3)$$

where s_{rot} is the structuring element s which is rotated by 180 degree. If a structuring element is symmetrical with respect to rotation, then s_{rot} will not differ from s. Many operations are performed by both erosion and dilation.

$f^c(x, y) = 1$ if $f(x, y) = 0$, $f^c(x, y) = 0$ if $f(x,y) = 1$

where, $h = f \cap g$, *f*, and g are two images.

So, $h(x, y) = 1$ if $f(x, y) = 1$ and $g(x, y) = 1$, and otherwise $h(x, y) = 0$

If $h = f \cup g$, then $h(x, y) = 1$ if $f(x, y) = 1$, $g(x, y) = 1$, and otherwise $h(x, y) = 0$

Opening of an image is erosion followed by dilation. Opening of an image *f* with structuring s element is represented by:

$$f \circ s = (f \ominus s) \oplus s \quad \ldots\ldots(4)$$

The closing operation is dilation followed by erosion, as shown in Fig. 3.13. Closing of an image f with structuring element s is represented by the following equation:

$$f \bullet s = (f \oplus s_{rot}) \ominus s_{rot} \quad \ldots\ldots(5)$$

It is observed that there were many small holes in the images after find connectivity. If it is desired to remove small holes while retaining large holes, then we can simply perform closing operation, as shown in Fig.3.14. Previously it is discussed that closing operation is dilation followed by erosion and dilation and erosion is done by a small structuring element. The uses of dilation are to fill in small background holes in images. But the problems are that the dilation will also distort all regions of pixels indiscriminately. By performing erosion on the image after the dilation it is possible to reduce some of this effect.

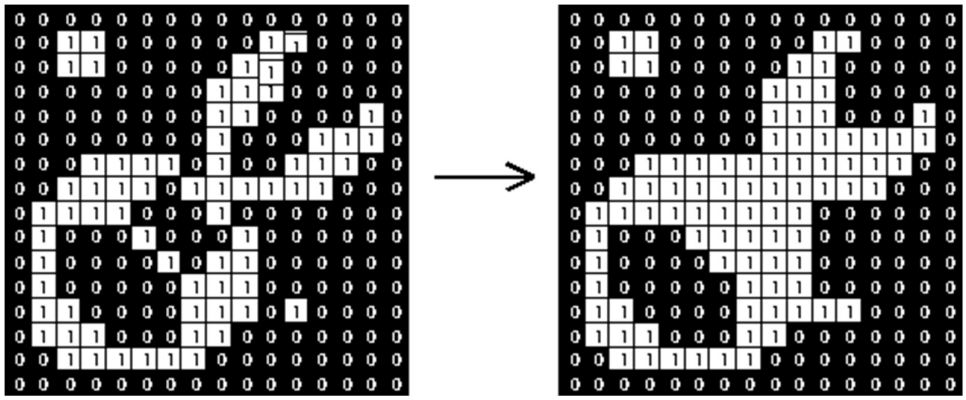
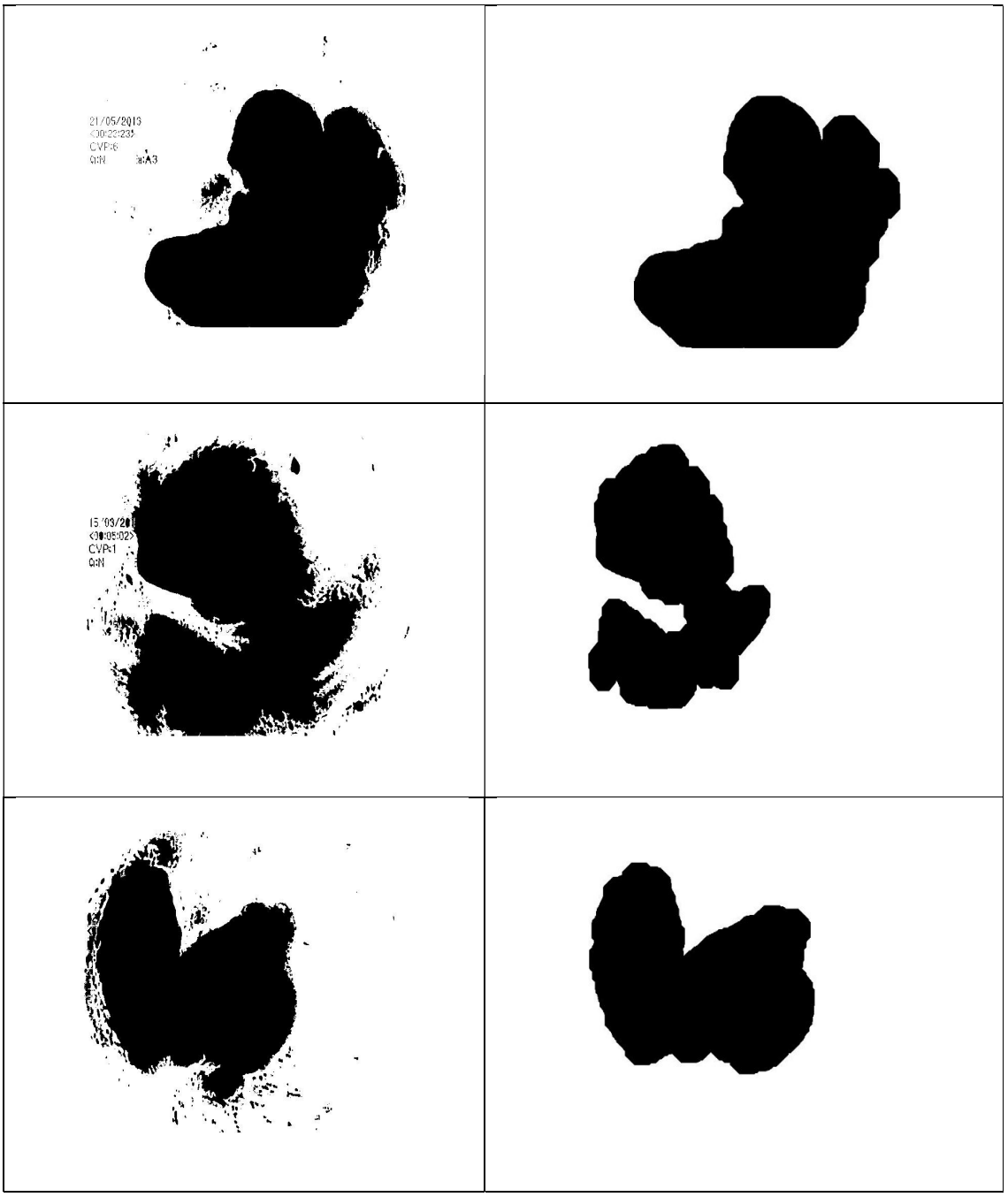


Fig. 3.13 Closing operation on a binary image

Connected component	Image after morphological operation
	



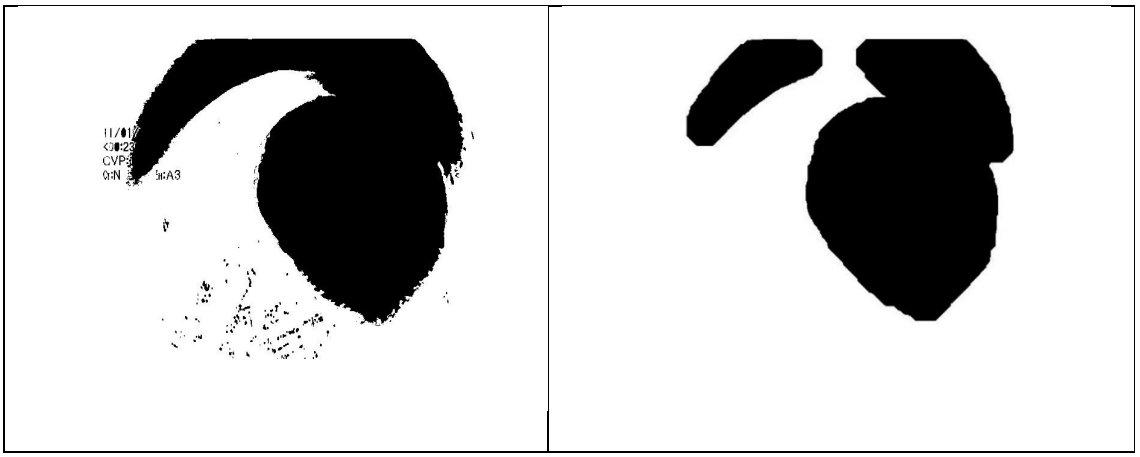


Fig. 3.14 Pictorial representation of polyp images after morphological operation

CHAPTER 4

CHAPTER 4

Dataset Preparation And Results

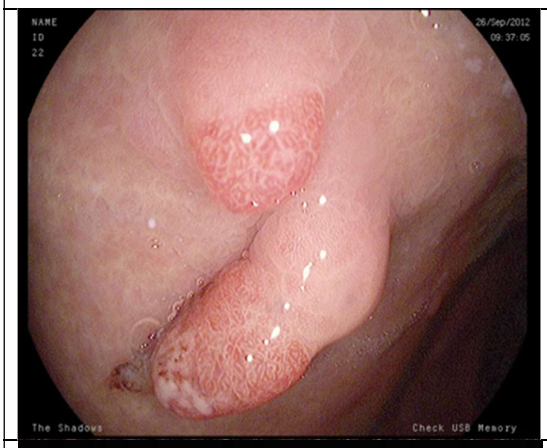
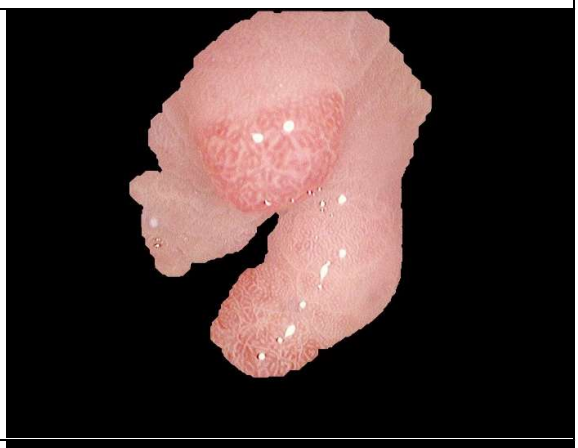
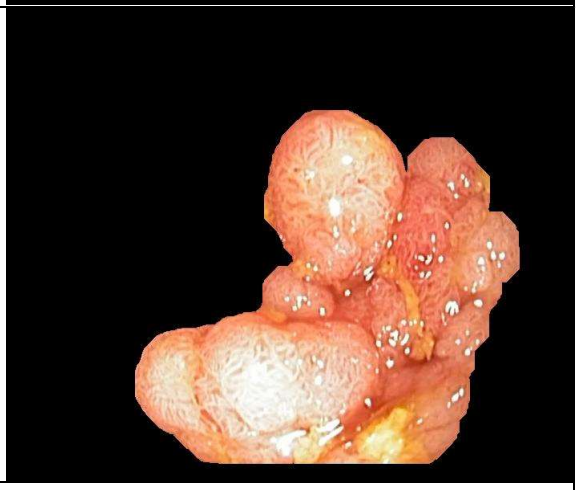
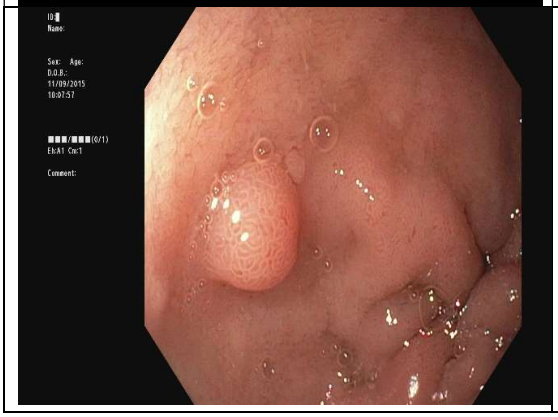
4.1 Dataset Preparation

To evaluate the above proposed method, kvasir dataset was used. Kvasir database is an open source dataset which contains an image from inside the GI(gastrointestinal) tract. In addition, it contains several classes showing anatomical landmarks, pathological findings or endoscopic procedures in the GI tract. So it has hundreds of images for each class. The anatomical landmarks consist of Z-line, pylorus, cecum, etc., while the pathological finding includes esophagitis, polyps, ulcerative colitis, etc. The data were collected with endoscopic instruments which are health trust. The dataset consists of images annotated and verified by medical doctors. The dataset consists of the images with different resolution from 720x576 to 1920x1072.To verify the proposed method 1500 polyps data from this dataset was taken.

4.2 Results

According to the source of the dataset, polyps are flat, elevated, pedunculated, and can be distinguished from normal mucosa by color and surface pattern. The proposed method is evaluated on 1500 images of polyps and it successfully segmented around 93.27% of the polyp region irrespective different image resolution. The results were verified by, a reliable and expert physician from Medica Super Speciality Hospital, Kolkata.

$$Accuracy = \frac{correctly\ segmented\ image}{Total\ number\ of\ polyp\ image}$$

Input polyp images	Final segmented polyp images
	
	
	

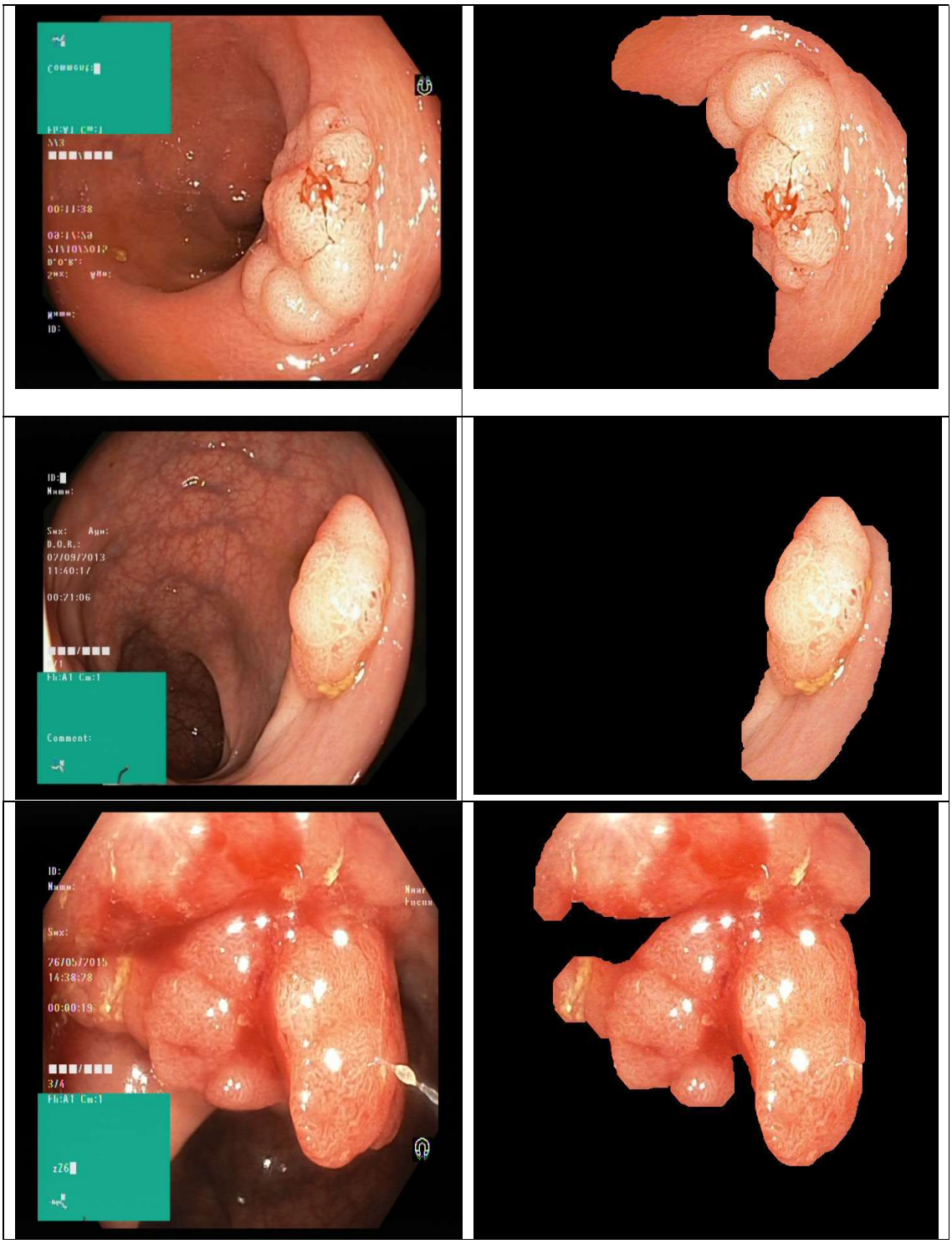


Fig. 4.1 Input polyp images and final segmented polyp images

CHAPTER 5

CHAPTER 5

CONCLUSION AND FUTURE SCOPE OF THIS WORK

In this thesis, a simple but effective approach to automatically segment polyps from endoscopic images is presented. This segmentation method based on thresholding and morphological operation. The segmented region characterized by colour based feature. These experiments demonstrate that the proposed method can segment polyps' images by 93.27% accuracy. This segmentation problem is still challenging because of various shapes and size of polyps, illumination effect, camera angles, etc. More sophisticated segmentation process will be designed for more efficient polyp detection.

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