Final Year Project Report

Polyp Detection System
B.S. Software Engineering, Batch 2017

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Submitted by

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October 2019 to November 2020

Preface

Colon cancer is one of the leading causes of death worldwide, and the most reliable way to diagnose and prevent it is colonosopy. We aimed to reduce the possibility of the doctor missing the polyp through Machine Learning. Our special focus in developing the project was to come up with User Interface which is as minimally distracting as possible, and at the same time providing key features at the fingertips.

Throughout the project, we learned how to work as a team, best way to communicate and iterate over our ideas so as to produce quality software. We took visits of the hospitals and the colonoscopy department to gain an insight about how our project would fit into the existing environment. We also took interviews with doctors who guided us around the problems they face. Overall, we got to learn alot, and experiment with our ideas. Seeing all our efforts into a working software feels amazing.

Acknowledgments

First of all, we would like to thank Almighty Allah who gifted us with the ability to think and reason. Secondly, we would like to express our special thanks of gratitude to our Project Internal Advisor Ms. Nida Khalil who guided and supported us throughout our project. We would also like to thank Sir Tauseef Mubeen for his unwavering support and time. We also want to show our gratitude to Dr. Mirza Muhammad Ali who gave their time to guide us in our project and Mr. Humza Sheikh for his suggesions to improve the UI. We are also grateful to parents and siblings who supported and motivated us to do our best.

Introduction to Group Members

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CERTIFICATE OF COMPLETION

This is to certify that the following students

Zeeshan Zulfiqar Ali	2017-SE-106
Shahab Younus	2017-SE-122
Zeeshan Amir Khan	2017-SE-108
Syyeda Dua Raza	2017-SE-097

Have successfully completed their Final Year Project named

Polyp Detection System

In the partial fulfillment of the Degree of Bachelor of Science in Software Engineering

Nida

Nida Khalil
Senior Lecturer
SSUET

Abstract

This report compiles and presents the work performed during the period of Final Year Project on Polyp Detection System. With aim to reduce the misclassification of polyps by doctors, we developed a software to assist doctors in the task. Our major effort went towards making sure to strike a perfect balance between ease of use, intuitiveness and advanced functionalities. We reviewed several research papers and compiled the findings and draw insights from them. In-detail diagrams are also shown in the Technical documentation section which helps visualize the inner workings of the system. The tradeoffs and considerations made through out the project are explained in the methodology.

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Chapter 1

Introduction

1.1 Overview

Cancer is one of the leading causes of deaths. It is a form of non-communicable disease. Cancer screening tests are performed in which the tumors are visually identified and removed. The most common of these tests is Colonoscopy. This procedure is of paramount importance as these tumors can grow into cancer if left untreated. Due to fatigue, the operator or doctor can miss the polyp, especially those which are small in size, but present the risk of cancer nonetheless. therefore we aim to exploit the recent progress in deep learning and computer vision to enhance the procedure.
This system is highly practical as it doesn't require the operator any extra time or special training. It can also be integrated with any existing equipment. The monetary cost is minimal and the system provides great value in terms of human lives.

1.2 Objectives

Following are the objectives of our system:

- Our major goal is to reduce the risk of colon cancer through timely and accurately detection of polyps.
- The endoscopy process will became less prone to error, as the software will alert endoscopists when it detect polyps.
- Our software will provide various means to detect polyps such as video, images and from the live transmission as well.
- Through this software, we can provide option to collect patient's data automatically which will help experts and researchers in their relevant researches.
- Through our effort, we hope to kick start the integration of cutting edge technology with medical procedures.

1.3 System Features

Following are the features which would be provided in the system:

- **Detection of polyp with high confidence.**
  The detection model would produce high confidence predictions.
- **Realtime detection**.
  The detection system would work in realtime.
- **Ability to make detections on already recorded video**.
  The system would also give an option to make detection on already recorded video.
- **Ability to make detection on a single picture**.
  The system would also give an option to make detection on a single picture.
- **Small alert to get the attention of doctor.**
  The system would generate a small alert to get the attention of the doctor when the polyp is detected.
- **Save live video with and without detection.**
  The system would also provide the feature to save the video feed with and without the detection.
- **Option to develop polyp dataset**.
  The system would also provide option to develop the polyp dataset on the go.
- **Ability for the doctor to correct the system**.
  The system will also provide option to the doctor to mark any detection by the model, a false positive or false negative.
- **Monitor DPI aware adjustment**.
  The system would automatically scale up or down all the UI according to the DPI of the screen, ensuring consistent User Interface accross different sized monitors.
- **Save Bookmarks**.
  The system provide feature to save the current position of video and a text as a bookmark.

Chapter 2

Literature Review

Paper I: Development and validation of a deep-learning algorithm for the detection of polyps during colonoscopy *Pu Wang et al.* [1]

Summary:

The detection of polyps is of utmost importance and a recognized standard in prevention of colon cancer. However, different endoscopist have different polyp detection rate which can have great impact on the procedure. In this paper, the authors show that a ML algorithm can detect polyps in real time which high precision. The authors developed a deep learning algorithm which was trained on data from 1,290 patients and validated on 27,113 images containing at least one polyp from 1,138 patients, on a public dataset of 612 images, on 138 colonoscopy videos with polyps and 54 full videos of colonoscopy without polyps. Using a multi-threaded architecture, the algorithm successfully processed at least 25 frames per second with low latency (approx. 76.80ms) in real time. The software developed may aid in the colonoscopy procedure and avoid accidental misidentification of a polyp by the endoscopist.

Paper II: Computer-aided diagnosis for colonoscopy *Yuichi Mori et al.* [2]

Summary:

The recent developments in Artificial Intelligence and computer vision, computer aided diagnosis in colonoscopy is gaining traction. The CAD facilitates automated detection and classification of polyps in real time which can help prevent accidental missing and undiagnosed polyps during the colonoscopy procedure, of utmost importance and a recognized standard in prevention of colon cancer. However, different endoscopist have different polyp detection rate which can have great impact on the procedure. The polyp miss rates can be as high as 20% which accuracy of physicians is only about 80% in detecting polyps. The authors suggest and identifies that there is a need for collaboration between experts in medical field and in engineering field, data needs to be collected, clinical trails need to be held to study effects of CAD and legal issue. The author predicts that all the hurdles will be overcome in next few years.

Paper III: Real-time automatic detection system increases colonoscopic polyp and adenoma detection rates: a prospective randomised controlled *Pu Wang et al.* [3]

Summary:

The polyp miss rate is among the few factors which cause colorectal cancer mortality after colonoscopy. Limited detection of adenoma is a problem. The authors researched the effects of an automatic polyp detection system on previous mentioned problems. A medical trial was conducted in which out of 1058 patients, 536 were randomly performed standard colonoscopy procedure and 522 were done with computer aided diagnosis. This result in an increased detection rate and increased number of mean adenomas per patient. This was mainly because of detection of small adenomas while number of large adenomas between the two groups was not much. The automatic polyp detection system during colonoscopy resulted in an increased number of detected polyps.

Paper IV: Computer vision and augmented reality in gastrointestinal endoscopy *Nadim Mahmud et al.* [4]

Summary:

Augmented reality is a technology which enhances the environment. It is very common in games but recently it has started to find its way in medical field. The authors realise that the gastrointestinal endoscope provides huge amount of data to the view in real time and find pathologic correlates. Author suggests that AR is well suited to provide computer guided assistance during the procedure to detect polyps. As operator fatigue is a real challenge, previous research has shown that polyp detection can be increased by 30% by having another professional. This shows that the potential for a computer system which can detect polyps with consistency can positively affect the polyp detection rate.

Paper V: Towards a Computer-Aided Diagnosis System in Colonoscopy: Automatic Polyp Segmentation Using Convolution Neural Networks *Patrick Brandao et al.* [5]

Summary:

For successful treatment of bowel cancer like colorectal cancer, early diagnosis is very important. Automated image analysis can prove beneficial in this regards. The authors present a deep learning based detection and segmentation framework for detecting polyps in colonoscopy images. The authors restructure established convolution architectures, for example VGG and ResNets, by converting them into fully-connected convolution networks (FCNs), fine-tune the hyper parameters and study their capabilities for polyp segmentation and detection. To recover depth and provide a richer representation of the tissue's structure in colonoscopy images, authors use shape-from-shading(SfS). Depth is incorporated into the network models as an additional input channel to the RGB information and the authors demonstrate that resulted in improved performance. The network are tested on publicly available datasets and the most accurate segmentation model achieved a mean segmentation interception over union (IU) of 47.78% and 56.95% on the ETIS-Larib and CVC-Colon datasets, respectively. For polyp detection, the top performing models we propose surpass the current state-of-the-art with detection recalls superior to 90% for all datasets tested. To our knowledge, we present the first work to use FCNs for polyp segmentation in addition to proposing a novel combination of SfS and

RGB that boosts performance.

Paper VI: Artificial intelligence technology in oncology: a new technological paradigm *Mario Coccia* [6]

Summary:

Artificial intelligence is the most demanding field in the area of technology, most of the things are leading towards the artificial intelligence. Artificial intelligence creates opportunity for the people, that machines or computer perform different tasks according to human intelligence. Here deep learning and machine learning is an important aspect in the field of artificial intelligence. Different algorithms are used to perform some specific task according to our requirement and machine is responsible for doing that task instead of humans. From the medical aspect artificial intelligence is helpful in different diagnoses, accurate detections like lung cancer, liver cancer or thyroid cancer. Cancer is the most distressing disease which has high death rate. If it will be detected at initial stages then there must be some chances to heal at the initial level otherwise most of the cases cause death. Approximate 9.6 million people died just because of cancer in 2018 and expectation is, in 2035 this estimation will be double. 60% cancer cases occur in low-to-middle income countries and death occurrence is 75% in these countries. Artificial intelligence may help to reduce by the initial detection of tumors and symptoms related to cancer under the supervision of expert clinicians.
Lung cancer is one of the most important disease and it may occur due to smoking, drinking or pollution etc. The probability of this type cancer is very high, about 2% to 10% people survive in that type cancer in past 5 year duration. The detection of lung cancer is like adenocarcinoma, squamous cell carcinoma, EGFR, ALK, T790, for diagnosing these process doctors need to do therapy which is may affect patient's life. So on the other side artificial intelligence and deep learning strategies are used for classification of lung tumors, bladder and breast symptoms. So if we talk about practical implementation, so here model must be trained according to requirements and deep learning technology conventional neural networks (CNN) used for accuracies for the classification of cancer. For training the data set millions of images must be required which visualize or recognize the lungs pattern or disease and on that bases it will be predict the right output. Same procedures used for thyroid and breast cancer.
In the fast growing world technologies are replacing layman work so by that means artificial intelligence plays a prominent role in modern world medical field and it helps doctors with high accuracy and efficiency in modern era.

Paper VII: Application of Artificial Intelligence in the Detection and Differentiation of Colon Polyps: A Technical Review for Physicians *Wei-Lun Chao et al.* [7]

Summary:

In this survey, we talk about polyp detection. Polyp is basically arises in the human body, if it detect in the early stages then it will be healed otherwise it move towards the cancer. For the detection of polyp doctors must do colonoscopy and during colonoscopy there must be risk of missing detection of polyp. So on the other side computer aided diagnosis (CAD) and artificial intelligence (AI) shows the promising result by the means of detection of polyp. In United

States, colorectal cancer is the third most leading cancer both in men and women which cause death in most of the cases. Fortunately in United States, effective screening techniques is the way by which colorectal cancer rate is decrease by past three decades. Adenoma is a benign tumor which can lead to cancer but its early detection through colonoscopies reduce the rate of its transformation into more aggressive state. Adenoma detection rate varies because it is operated by humans most of the 20% to 30% chances that it could be missed. So alternate way is computer aided diagnosis (CAD) which is computer assisted image analysis that is used to detect polyp at initial level. CAD and CNN models are used for colonoscopy which is working on the bases of neural network and performing image and video processing. Recent version of CAD models shows 89% to 95% accuracy in which 100 to 466 polyp detected according to research. Machine learning approach is used to train model. So for that labeled training data are collected, then model is divided into two parts feature extraction and classification, in that case feature extraction part require human effort whether machine learning algorithm can learn classification. For the image and video processing CNN's are the most important class of DNN's. All of the reasons behind these procedure is to CAD during colonoscopy. In CNN color image of polyp is detected with three dimensional, first two dimension represent width and height and the third one represent the color channel, by that means polyp pattern should be detected. For the detection of polyp models are trained by finding polyp and non-polyp region. Moreover for accuracy models are trained between hyperplastic versus adenomatous polyps. Through colonoscopy, the investigators examines how the classification of polyps fluctuates across successive frames. By the means of artificial intelligence detection of polyp investigators have the opportunity of accuracy and it integrate human and machine efforts.

Paper VIII: Artificial Intelligence & Medical Diagnosis *Abhishek Kashyap* [8]

Summary:

Technologies has a dominant role in our lives now a days like TV, watches, smartphones etc. In the eighteenth century first time picture of hand was captured, that's move towards the XRAYS in the way of medical. One of the most heard conditions is Predicting Cardiovascular Risk Factors using Retinal Fundus Photographs or Diabetic Retinopathy or Prediagnosing Osteoarthritis using Cartilage MRI or Stroke. So XRAY will became a one of the most prominent technology for diagnosing in medical and health care field. Google recently developed an algorithm which recognizes hidden pattern in retinal images. Approximate 280,000 images used to train and understand hidden patterns. Then it was validated on 999 patients. Artificial Intelligence save time and cost. It is used to analyze historic patterns and working on them when the patients of relevant disease approaches to the hospital then it provide pre-diagnosis and assist doctors in moving forward in the right direction of treatment. Watson Cloud & Targeted Real time Early Warning System (T.R.E.W.S.) are neural network which was trained by machine learning. This system is used to analyze like age, BMI, heart rate, exercise habits, eating habits, sleep pattern and your psychological behavior through various sensors, for example, your smartwatch, health band, your browsing history, mobile Phone activity. Another technology which is CATH-BOT that is robot which remotely supervises cardiac catheterization without any harmful ionizing radiation. A machine learning (ML) algorithm was developed considering structural, physical and chemical characteristics of these inhibitors. Three different functions of ML, Multilayer Perceptron (MLP), Logitboost (LB), & Decision Table (DT) were applied to set of Molecular Descriptors for an active and inactive compound in 5-fold cross validation. The highest accuracy achieved by this data set was 88.86% by MLP. The model developed is currently being employed for selection of possible drug candidate from the database of these compounds.

Paper IX: Polyp Detection in Colonoscopy Videos Using Deep-Learned Hierarchical Features *Sungheon Park, Myunggi Lee and Nojun Kwak* [9]

Summary:

The purpose of this method is to learn hierarchical features using convolutional neural networks. Each pixel in colonoscopy image is classified as polyp pixel or non-polyp pixel through fully connected network. The region of accuracy of this method is about 99%.

The main tool used in this proposed method is Convolutional Neural Network. Polyps have various colors and shapes. Especially, size are different, even the size of the same polyp can be varied as the camera moves. Therefore, with the help of learning multi-scale representation of polyp can improve the classification performance.

First of all, the border lines of the input are cropped. Then, triangular regions at the corner of the rectangular image i filled by reflection nearby image region. Because of this the rectangular image which do not contain black boundary region are generated. The image which is going to be trained will be cropped into small patches, and the patches are fed to the CNN in the proposed method. CVC-Clinic DB is used to organize training and test set. Each training image patch is locally normalized so that 15 x 15 neighbors have uniform mean and variance.

Each pixel of the test image should be classifies into polyp or non-polyp region. Extract patches of a test image in stride of 4. The resulting probability map is smaller in size as compared to original image, this method just made the test image equal the size of probability map. As a result, the probability that pixel is classified as polyp through the dense probability map.

Through the CNN trained, single image patch returns 60 dimension feature vector. To make use of multi-scale representation, features from the patch of the same location with different scales are concatenated. Also, 180 dimension feature vector is generated. Using the multi-scale feature vector, 2-layer fully connected network is trained. This has one hidden layer with 256 hidden nodes. The cost function of the classification layer is same as above equation. It is trained by stochastic gradient including the CNN and the fully connected network which is illustrated in Figure 1.

Preliminary results on CVC-Clinic DB are illustrated in this section. To check the performance of classifier and CNN, randomly selection of 50 pixels of polyp and non-polyp regions is done in each image of the validation set and test the patches to classify the selected pixel is polyp or non-polyp region. 91.60% of the test pixels classified as polyp region or non-polyp region, among 600 test pixels. This method detected 48 polyps among 64 polyps in 62 images, which means 75% accuracy of detection rate.

To modify the algorithm so, that the detection quality improves. Tuning the CNN parameters can affect the performance. For feature learning addition of regularization cost is necessary. Labeling method can be improved by post-processing step. This modification can reduce the rate of false alarms in test images.

Paper X: Automated Polyp Detection System in Colonoscopy Using Deep Learning and Image Processing Techniques *Y. Kopelman et al.* [10]

Summary:

The major cause of interval cancer of the colon is because of undetected colonic polyps. During screening colonoscopy the Automatic Polyp Detection System enhance the ability of endoscopists to detect polyps. It can be used in real time as well as offline; APDS highlights polyps on the screen by working directly on the video output of the endoscopic camera. In order to improve polyp detection rates, APDS utilizes the power of Deep Learning and computer vision thus improving the performance of the endoscopists.

This study measured the performance of the prototype using video sequences of about half a minute each: 75 sequences to train the system, 10 sequences to validate the training, and 35 sequences to test the trained system. The total database of training, validation and testing included 121,500 video frames featuring 120 different polyps. Free Response Operating Characteristics (FROC) function, which represented the system performance, was measured. True Positive Rate (TPR) expressed system sensitivity and False Positive Per Frame (FPPF) signified the complement of the system's specificity. The FROC was produced by changing the threshold parameter values of the system. For each threshold value, the number of polyps detected in at least 3 different consecutive frames was calculated. To obtain SPDR, this number is divided by the total number of polyps produced.

The APDS operated through DML in which multifactorial supervised learning algorithm is involved. After the data is learned and checked and the software applied, there is a continuous process of quality control and the software changes and adjusts according to the flux of new data. Compared to other diagnostic DML systems that have been studied and have received regulatory approval, the APDS takes the DML technique, CNN based, to a new level-the endoscopy and to a new type of data-video which also includes consideration of a temporal aspect when being analyzed. The APDS should meet the requirements as a clinically helpful tool. Comparing to another updated work that was published in 2018 on using artificial intelligence system for automatic polyp detection, it seems that the APDS has similar sensitivity but higher specificity. In addition, it should be noted that under specific circumstances, such as an unclean colon or rapid movements of the endoscope in the colon, it is expected that also the APDS could miss polyps. Therefore, the endoscopist will still have to remain alert, but will have the support of additional expert observer with a trained technological "eye" watching and analyzing the video. The endoscopist will have the option to ignore the system recommendations, but the system can register, using its tracking algorithm, the general location of untreated polyp to be reminded later on if needed. Finally, as more technologies are introduced to improve vision behind the colonic folds, more polyps can be expected to appear in the video, and thus the APDS is expected to be even more effective.

The goal of high automated colonoscopic imaging polyp detection rate ($\geq 95\%$) with high specificity ($\geq 98\%$) will be achieved by exposing the system to greater amounts of data during the training phase and adding more computer vision and logic capabilities to the system.

Paper XI: Guidelines for Colonoscopy Surveillance after Screening and Polypectomy: A Consensus Update by the US Multi-Society Task Force on Colorectal Cancer *Y. Kopelman et al.* [11]

Summary:

Incidence and morality of CRC can be reduced in asymptomatic patients by screening. In US, the most common screening test is colonoscopy. The most common neoplasm found during

CRC screening are Adenomatous polyps. Subsequent neoplasia reduced once patient had negative findings on colonoscopy or had low-risk adenomas, this was the key goal to achieve. The patients who have inflammatory bowel disease or prior history of CRC were removed from studies. Reviews to exclude patients with hereditary syndromes and average-risk individuals associated with CRC. In past six years there were no high quality randomized controlled trials of polyps surveillance performed. Low-risk adenoma (LRA) refers to patients with 1–2 tubular adenomas $<$10 mm in diameter. High-risk adenoma (HRA) refers to patients with tubular adenoma $\geq$10 mm, 3 or more adenomas, adenoma with villous histology, or HGD. Advanced neoplasia is defined as adenoma with size $\geq$10 mm, villous histology, or HGD. A total of 20%–30% of CRCs arise through a molecular pathway characterized by hypermethylation of genes, known as CIMP. Precursors are believed to be serrated polyps. Tumors in this pathway have a high frequency of BRAF mutation, and up to 50% are microsatellite unstable. CIMP-positive tumors are overrepresented in interval cancers, particularly in the proximal colon. The principal precursor of hypermethylated cancers is probably the sessile serrate polyp (synonymous with sessile serrated adenoma). These polyps are difficult to detect at endoscopy. They may be the same color as surrounding colonic mucosa, have indiscrete edges, are nearly always flat or sessile, and may have a layer of adherent mucus and obscure the vascular pattern. The task force believes that quality indicators must be measured as an essential part of a colonoscopy screening and surveillance program.

Chapter 3

Technical Documentation

3.1 DFD Diagrams

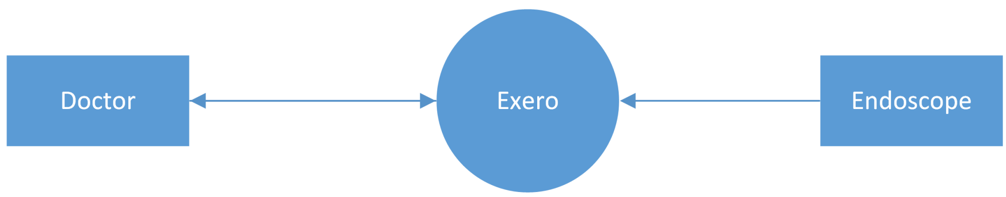

Figure 3.1: DFD Level 0

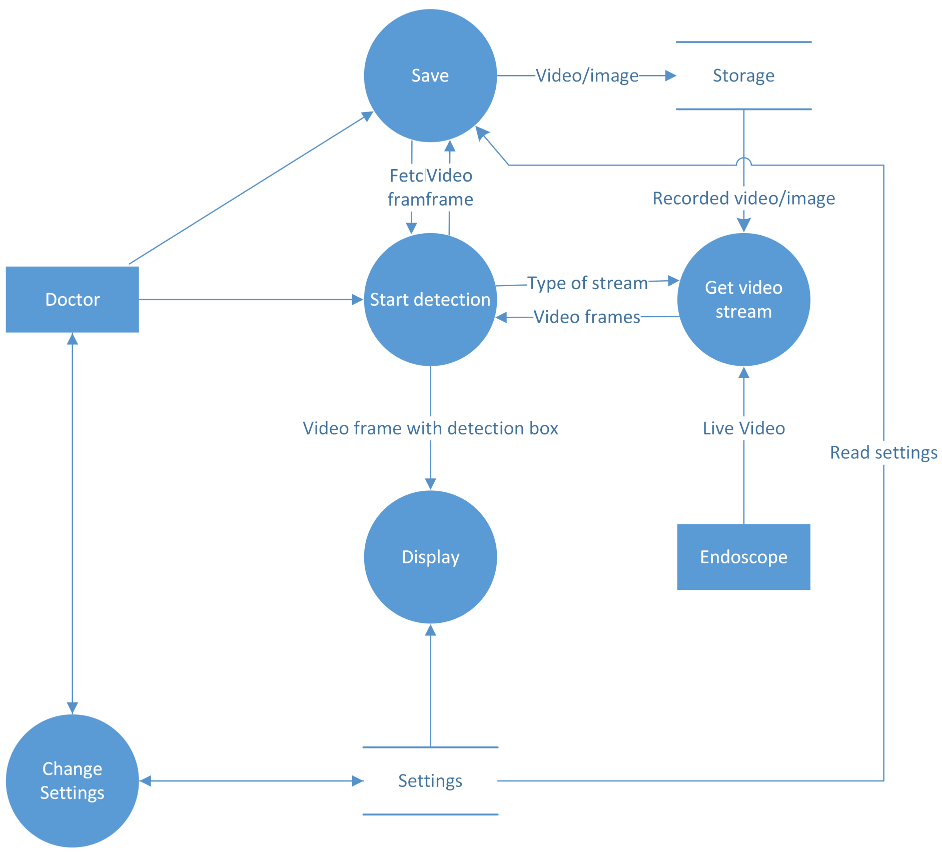

Figure 3.2: DFD Level 1

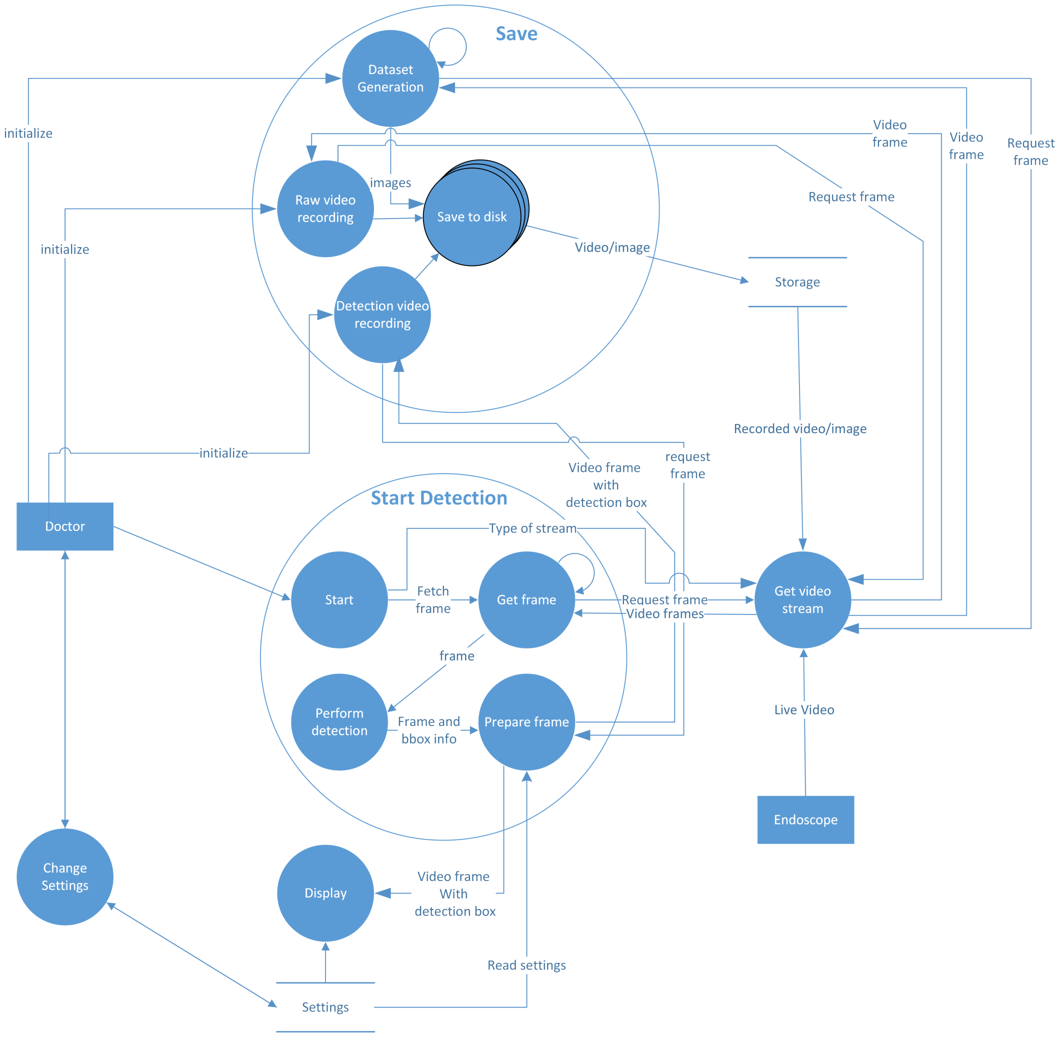

Figure 3.3: DFD Level 2

3.2 Use Case Diagrams

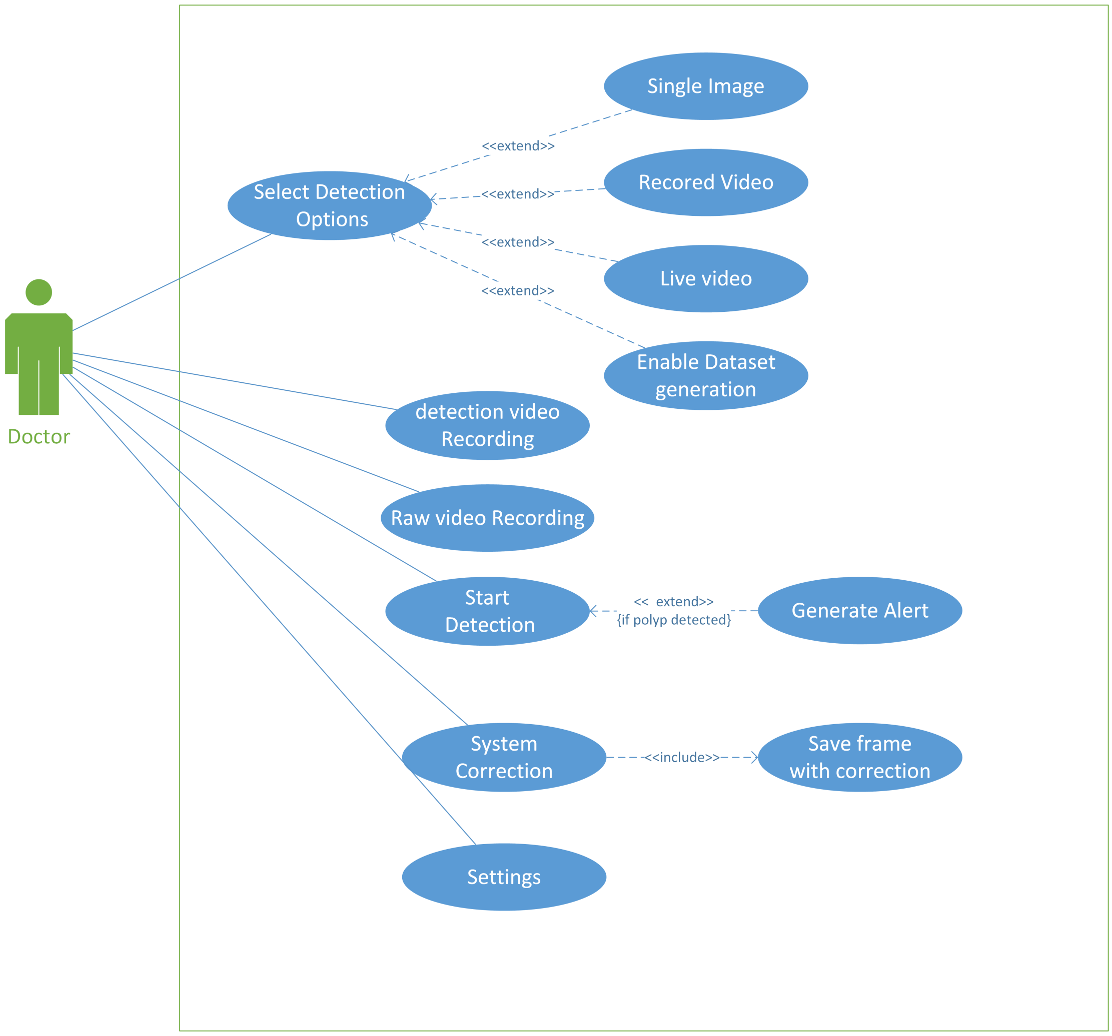

Figure 3.4: Usecase diagram for Polyp Detection System

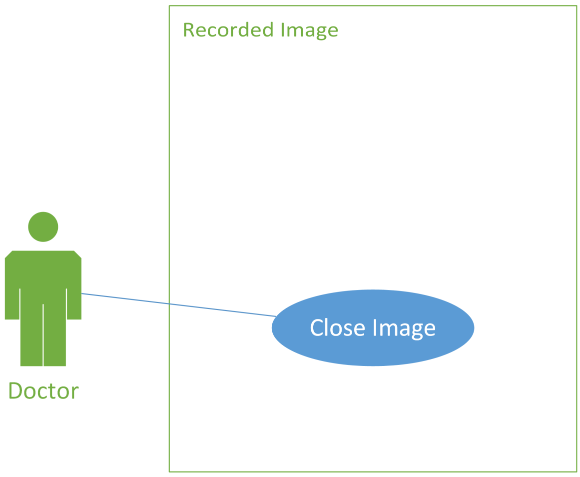

Figure 3.5: Usecase diagram for recorded image functionality

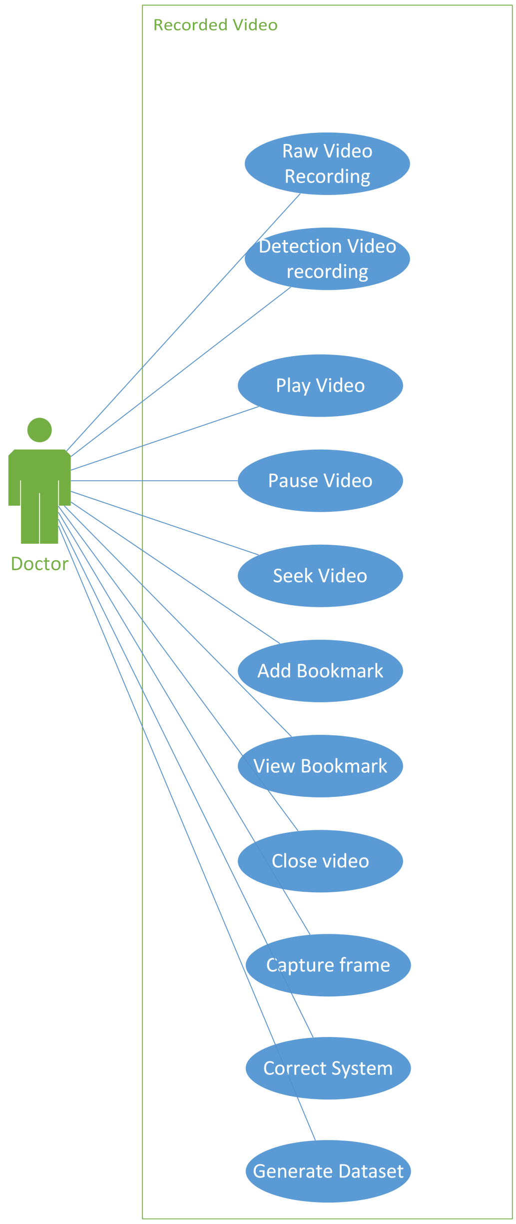

Figure 3.6: Usecase diagram for recorded video functionality

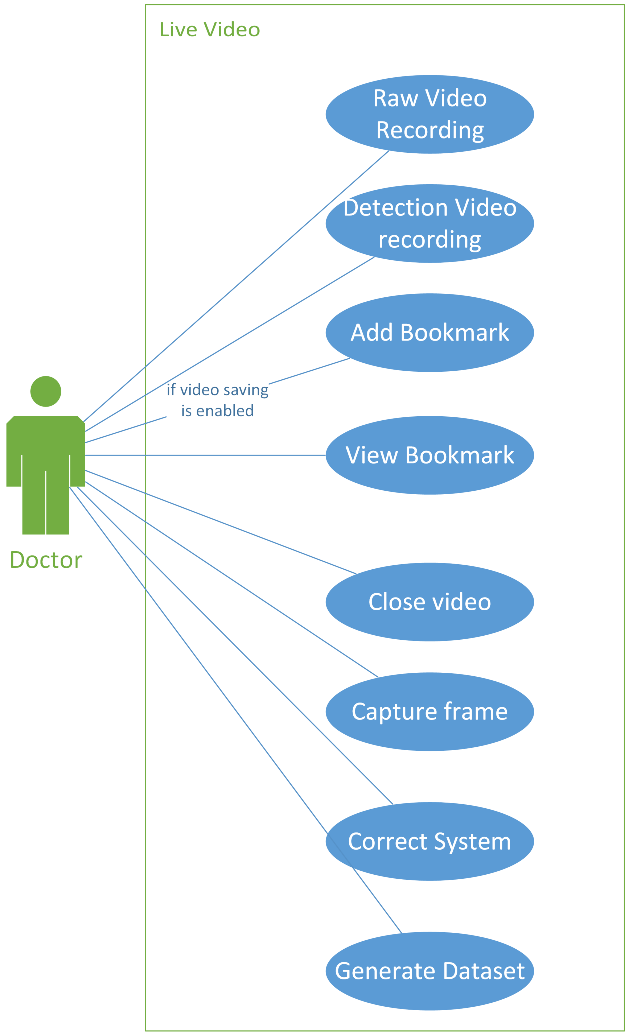

Figure 3.7: Usecase diagram for live video functionality

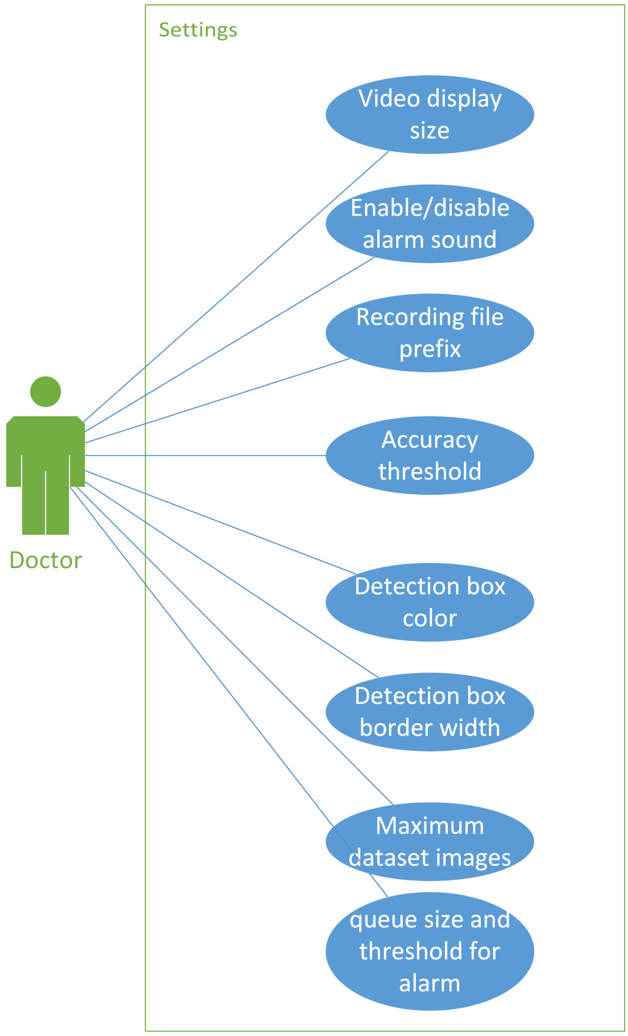

Figure 3.8: Usecase diagram for Settings

3.3 Stakeholder Register

Table 3.1: Stakeholder register

Name of stakeholder	Role	Role in Project	Type of Communication	Expectations
Ms. Nida khalil	Lecturer	Internal advisor	fortnightly via video call or email	Project on time according to the requirements
Zeeshan	Student	Leader / Developer	messaging services, email, calls.	Timely development of project with quality assured
Shahab	Student	ML	messaging services, email, calls.	No bugs make to the final build
Dua Raza	Student	UI designing	messaging services, email, calls.	UI is as efficient as possible
Zeeshan Amir	Student	Tester	messaging services, email, calls.	Model works as expected

3.4 Risk Register

Table 3.2: Risk Register

ID	Risk description	Probability of risk occuring	Impact if the risk occurs
1	Project requirement not defined well	20%	High
2	Project design incomplete	30%	High
3	Model doesn't perform well	25%	Medium
4	Team member becomes unavailable	5%	High
5	Data loss	10%	High

3.5 Gantt Chart

Table 3.3: Gantt Chart Table

	Task Name	Duration	Start	Finish	Predecessors
1	**Polyp Detection System**	**189 days**	**Mon 2/24/20**	**Thu 11/12/20**	
2	**Planning**	**19 days**	**Mon 2/24/20**	**Thu 3/19/20**	
3	Problem Statement	2 days	Mon 2/24/20	Tue 2/25/20	
4	Use case diagram	3 days	Wed 2/26/20	Fri 2/28/20	3
5	Sequence diagram	1 day	Mon 3/2/20	Mon 3/2/20	3,4
6	Block diagram	1 day	Wed 2/26/20	Wed 2/26/20	3
7	Activity diagram	2 days	Mon 3/2/20	Tue 3/3/20	3,4
8	Class diagram	5 days	Mon 3/2/20	Fri 3/6/20	3,4
9	DFD diagram	3 days	Mon 3/9/20	Wed 3/11/20	8
10	Document deveopment	6 days	Thu 3/12/20	Thu 3/19/20	3,4,5,6,7,8,9
11	**Data Collection**	**20 days**	**Fri 3/20/20**	**Thu 4/16/20**	
12	Dataset collection by polyp type	8 days	Fri 3/20/20	Tue 3/31/20	10
13	Data Cleaning	8 days	Wed 4/1/20	Fri 4/10/20	12
14	Dataset merging	3 days	Mon 4/13/20	Wed 4/15/20	13
15	Dev/Test set generation	1 day	Thu 4/16/20	Thu 4/16/20	14
16	**Model Designing And Testing**	**68 days**	**Fri 4/17/20**	**Tue 7/21/20**	
17	Model Supporting Code	8 days	Fri 4/17/20	Tue 4/28/20	15
18	Deep Learning Model Architecture Creation	35 days	Wed 4/29/20	Tue 6/16/20	17
19	Deep learning Model Training	15 days	Wed 6/17/20	Tue 7/7/20	18
20	Model Testing	10 days	Wed 7/8/20	Tue 7/21/20	19
21	**Development**	**92 days**	**Wed 4/29/20**	**Thu 9/3/20**	
22	Alarm Module coding	4 days	Wed 4/29/20	Mon 5/4/20	17
23	Video Module coding	16 days	Wed 4/29/20	Wed 5/20/20	17
24	Image Module Coding	1 day	Wed 4/29/20	Wed 4/29/20	17
25	Dataset generation code	6 days	Wed 4/29/20	Wed 5/6/20	17
26	Adding video saving feature to Model supporting Code	8 days	Wed 4/29/20	Fri 5/8/20	17
27	GUI development	58 days	Thu 5/21/20	Mon 8/10/20	22,23,24,25,26
28	Application enhancements by Multithreading	8 days	Tue 8/11/20	Thu 8/20/20	27
29	Optimizing Desktop Application	10 days	Fri 8/21/20	Thu 9/3/20	28
30	**Testing**	**30 days**	**Fri 9/4/20**	**Thu 10/15/20**	
31	BlackBox testing	10 days	Fri 9/4/20	Thu 9/17/20	29
32	Whitebox testing	10 days	Fri 9/4/20	Thu 9/17/20	29
33	System Testing	10 days	Fri 9/18/20	Thu 10/1/20	31
34	Application Improvement and Streamlining	10 days	Fri 10/2/20	Thu 10/15/20	33
35	**Documentation**	**20 days**	**Fri 10/16/20**	**Thu 11/12/20**	**34**

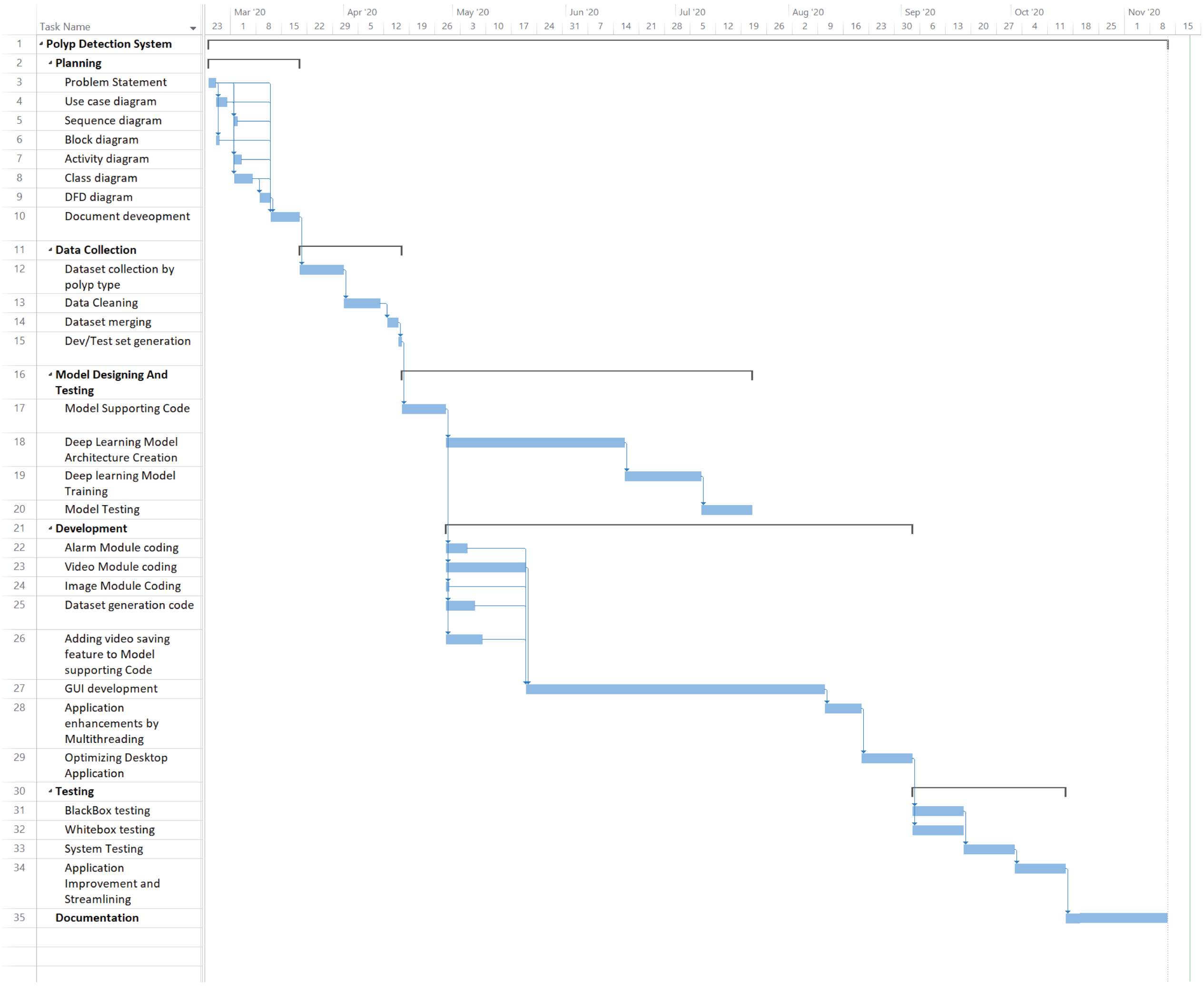

Figure 3.9: Gantt Chart

Chapter 4

Methodology

4.1 Design phase

The proposed solution to the problem described above is the use of advancements in the field of deep learning to develop an intelligent system which can detect polyps by using object detection algorithms. The colonoscopy uses an endoscope which has a camera. During the procedure, the doctor views the live video on a monitor. Our system would replicate the video, pass it into our system and display the output on a monitor. This setup is ideal as it would require minimum interaction of operator and the alarm/alert would get the attention of the doctor only when required. It also doesnt́ require any special training and the learning curve is also minimal.
The system UI is made with great care to make sure that color scheme doesn't cause eye fatigue in long term use. Using the system is straight forward too; after Launging the program, the user is presented with three ways to start the detection, by live video, recorded video, or recorded picture. Live video further asks to choose the camera they want to use. After selection, the detection starts rightaway and the video is shown in the center of the screens. User are also presented with options they might need on the left hand side in a collasible panel. This makes the user experience better but allowing the user to get the options out of the way and access them back with a single click. All the main features are presented in this side panel which makes it super easy to use.
When polyp(tumor) is detected, a sound alert is played to catch attention of the doctor. This can be turned off incase doctor founds it distracting. An algorithm is designed and implemented to make sure that the sound is played only when the model is really sure of the polyp, and to be able to brace if model incorrectly doesn't detect frame.

4.2 Implementation phase

Python was the language used to develop the system as it is very easy to use and the popular machine learning libraries have great python support. For the machine learning part of the application, we used Tensorflow and its open source Tensorflow Object Detection API to train our model using transfer learning. Numpy was used for handling the image data. PyQt is used to develop a UI. QThreads from PyQt were utilized to make the system multithreaded and responsive. OpenCV was also used to handle the video stream. The end result is a multi-threaded python desktop application.

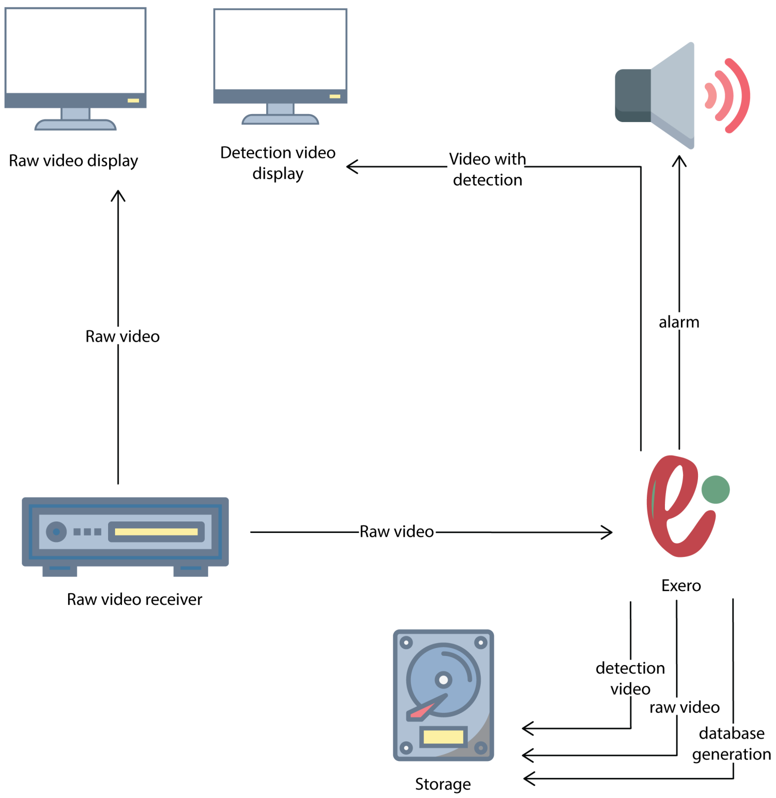

Figure 4.1: System Diagram

Chapter 5

Experiments & Results

The model chosen was SSD Inception v2 as it has a good inference time and can be used in realtime. Tensorflow Object detection API was utilized to transfer learn on this model using different hyperparameters. The comparison of these is shown in the table 5.1. The dataset Kvasir-SEG was used [12] which contains 1000 images of polyps. The same dataset was used on all the variants of model. The findings are as follows

- We found that increasing the learning rate reduced the accuracy.
- Adam optimizer didn't perform well.
- AutoAugmentation was instrumental in getting good performance as the dataset was quite small.
- Adding dropout also helped avoid overfitting.

Table 5.1: Comparison of different model hyperparameters

Models	**mAP@.50IOU**	**Loss**
SSD Transfer Learning 25000 epochs, rmsProp, dropout90, lr0.004	**0.904**	1.17
SSD Transfer Learning 15000 epochs, rmsProp, dropout90, autoaugment, lr0.004, step 2000, decayRate95	**0.904**	**0.667**
SSD Transfer Learning 25000 epochs, adam, dropout90, autoaugment, lr0.004, step 2000, decayRate95	0.782	0.88
SSD Transfer Learning 10800 epochs, rmsProp, dropout90, autoaugment, lr0.045, step 2, decayRate94	0.861	3.37
SSD Transfer Learning 12914 epochs, rmsProp, dropout90, autoaugment, lr0.045, step20, decayRate94, gradClip2.0	0.887	1.43

The second model in the table above was selected for final use in the application. Its accuracy is given in figure 5.1 , loss in figure 5.2 , and learning rate in figure 5.3.

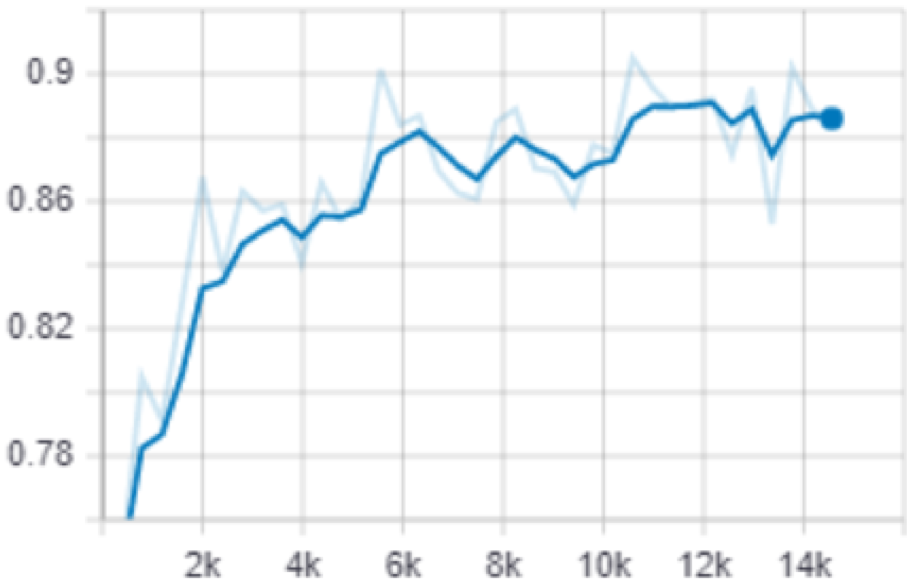

Figure 5.1: Accuracy of model

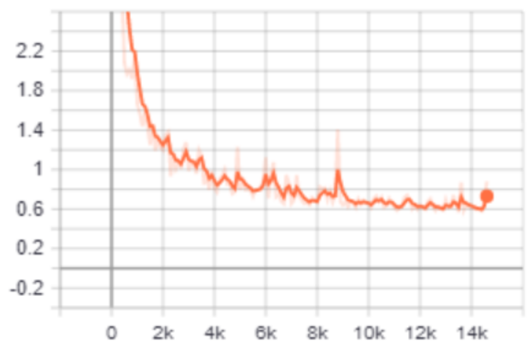

Figure 5.2: Loss throughout the training

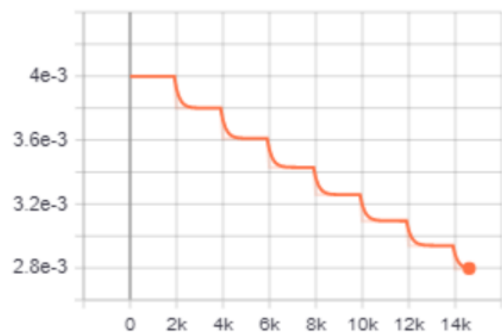

Figure 5.3: Learning rate with decay rate 95 and step 2000

Chapter 6

Costing

- For all Project Categories (Use COCOMO Model)

Our software is totally based on software therefore it lies in the organic category for COCOMO estimation model. Calculating Lines of code in different parts of Software:

Table 6.1: Lines of code written in development of Exero

Technology	**Lines of Code (in K)**
Application development	6
Model development	0.5
Total	6.5

According to the basic COCOMO model;

a = 2.4, b = 1.05, c = 2.5, d = 0.38,

$Effort = a(KLoc)^b$
$Effort = 2.4(6.5)^{1.05}$
$Effort = 17.130 Person - Months$

$Time = c(Effort)^d$
$Time = 2.5(17.130)^{0.38}$
$Time = 7.358 Months$

$Personrequired = \frac{Effort}{Time}$
$Personrequired = \frac{17.130}{7.358}$
$Personrequired = 2.328 Persons$

if Average Salary of 1 person is 35,000 per month, then

$Cost = Average salary \times Person required \times Time$
$Cost = 35000 \times 2.328 \times 7.358$
$Cost = PKR 599,530$

Chapter 7

User Manual

Our polyp detection system is developed by the name of Exero, which bears the literal meaning to reveal. This section will show you how to use and operate Exero.

7.1 Getting Started

7.1.1 Installing

Installing Exero is very straightforward:

1. Make sure that rar extracting software like winrar is installed. Locate the setup file, right-click on the icon and select "Extract files..."

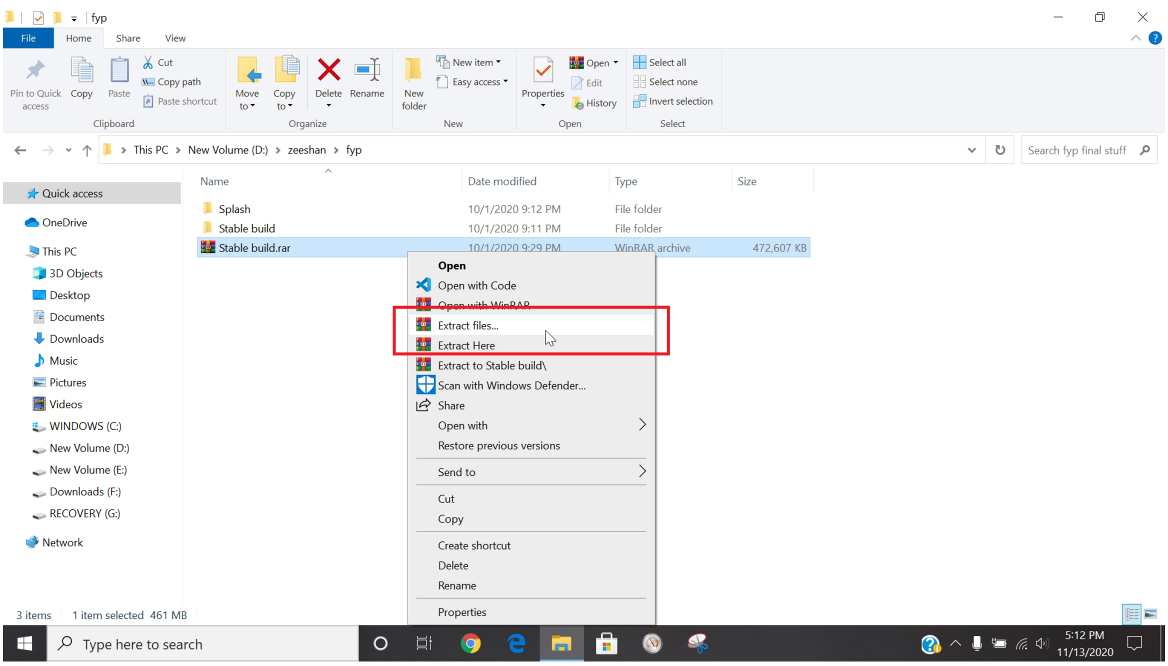

Figure 7.1: Extracting files

2. Select a directory to extract the files, and click ok

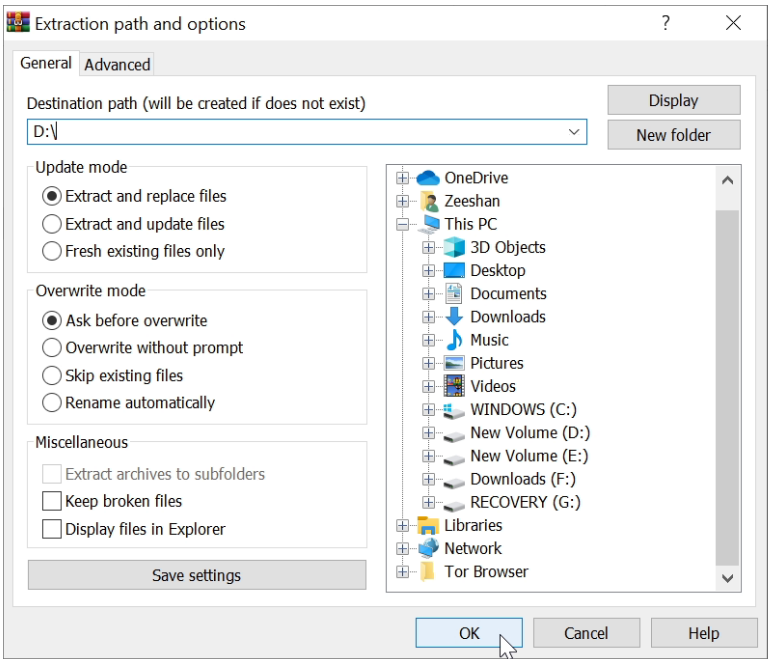

Figure 7.2: Selecting directory to extract files

3. Files will now be extracted to the specified directory

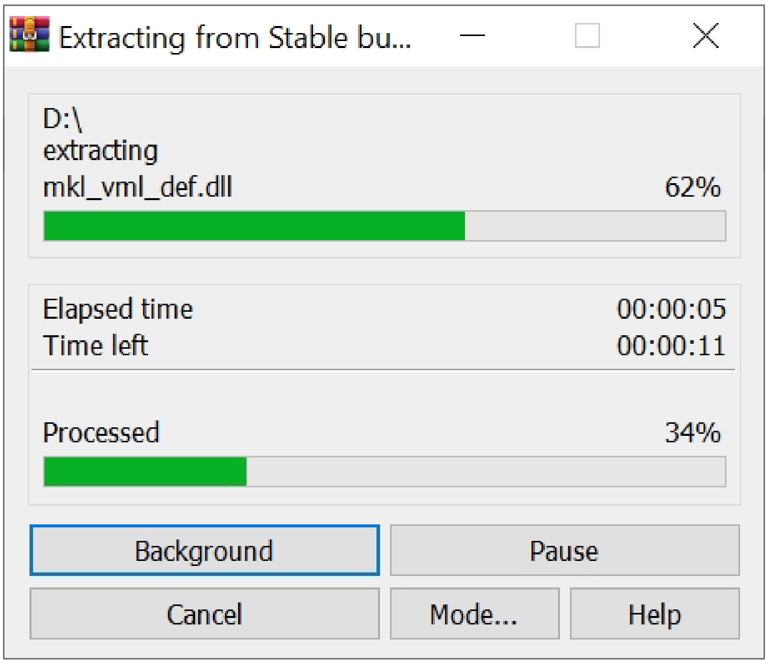

Figure 7.3: Files being extracted

4. Open the folder of extracted files. Navigate to the folder named Exero. Find an executable named Exero.exe and double click to execute.

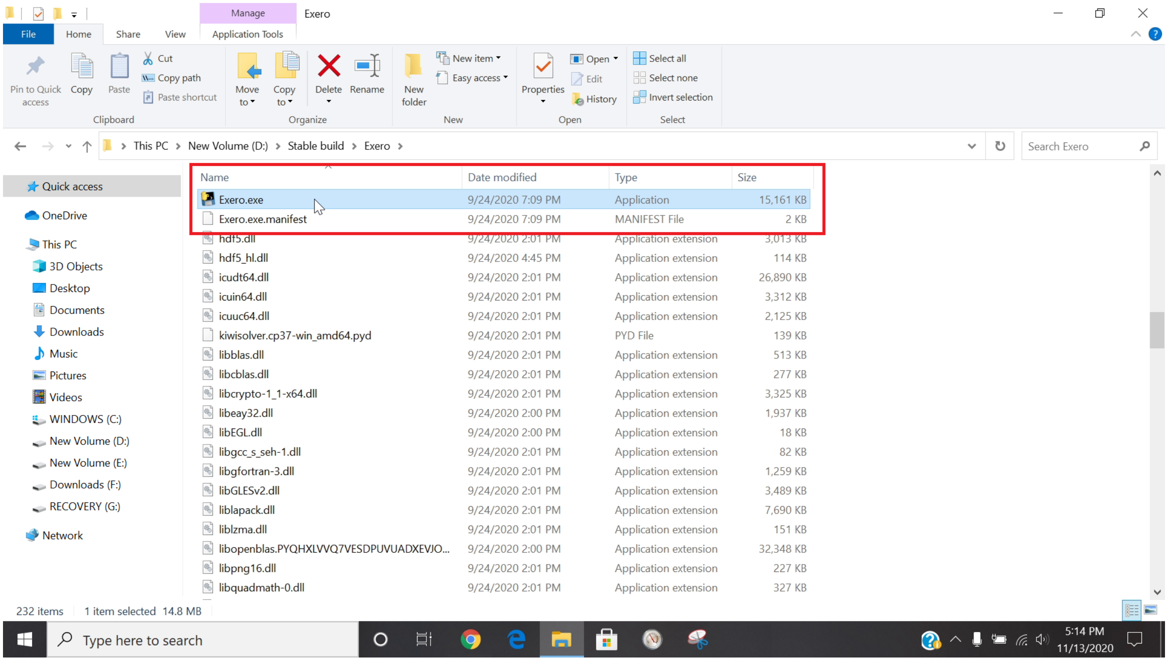

Figure 7.4: Locating the Exero executable

7.1.2 Starting a detection

After launching exero, you would have this interface:

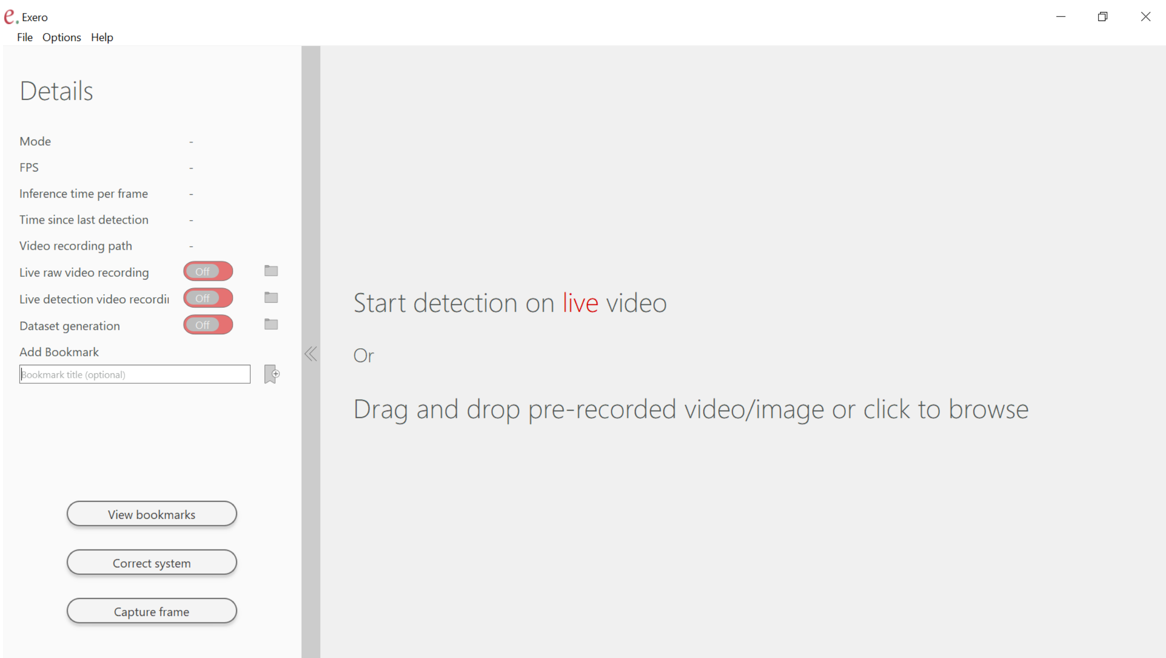

Figure 7.5: Exero

1. You can start detection in two ways: Live or recorded.

   (a) For live video, click on "Start detection on live video". You'll get a popup asking you to select the camera to perform the detection on from a list of cameras available to Exero.

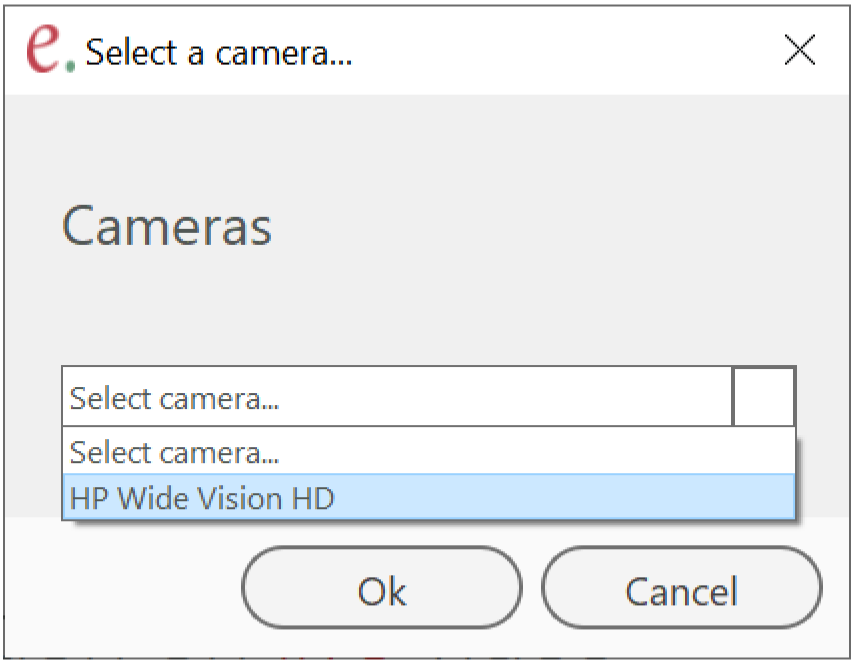

Figure 7.6: Popup asking to select the camera

(b) For recorded video or image, click on "click to browse". You'll get a popup asking you to select the file. By default, videos are selected, but to choose images, click on the dropdown just above the open and cancel button and select Images. This will now show all the images only.

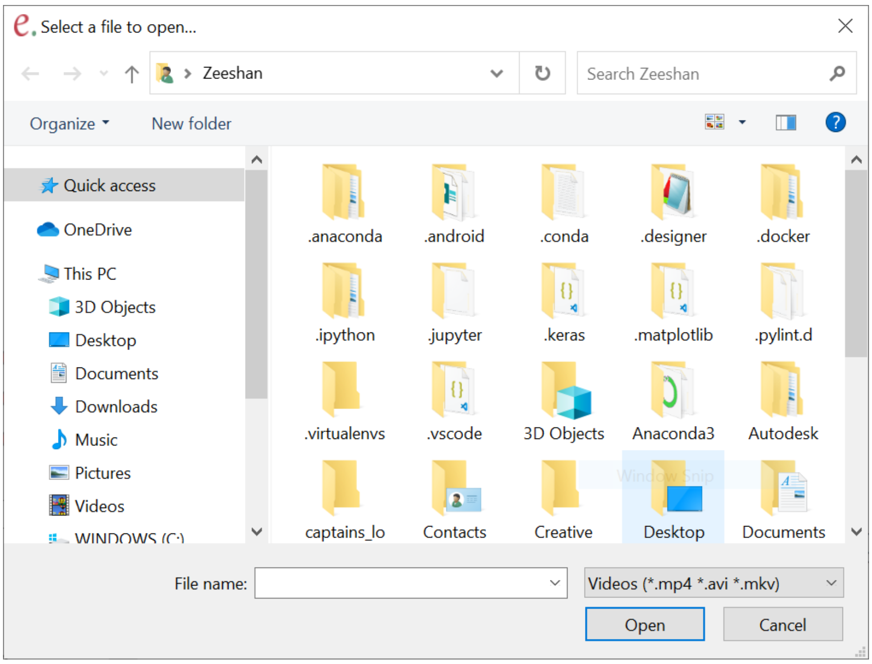

Figure 7.7: Popup asking to select the recorded video or image

(c) Pre-recorded videos and images can also be dragged and dropped directly to begin the detection.

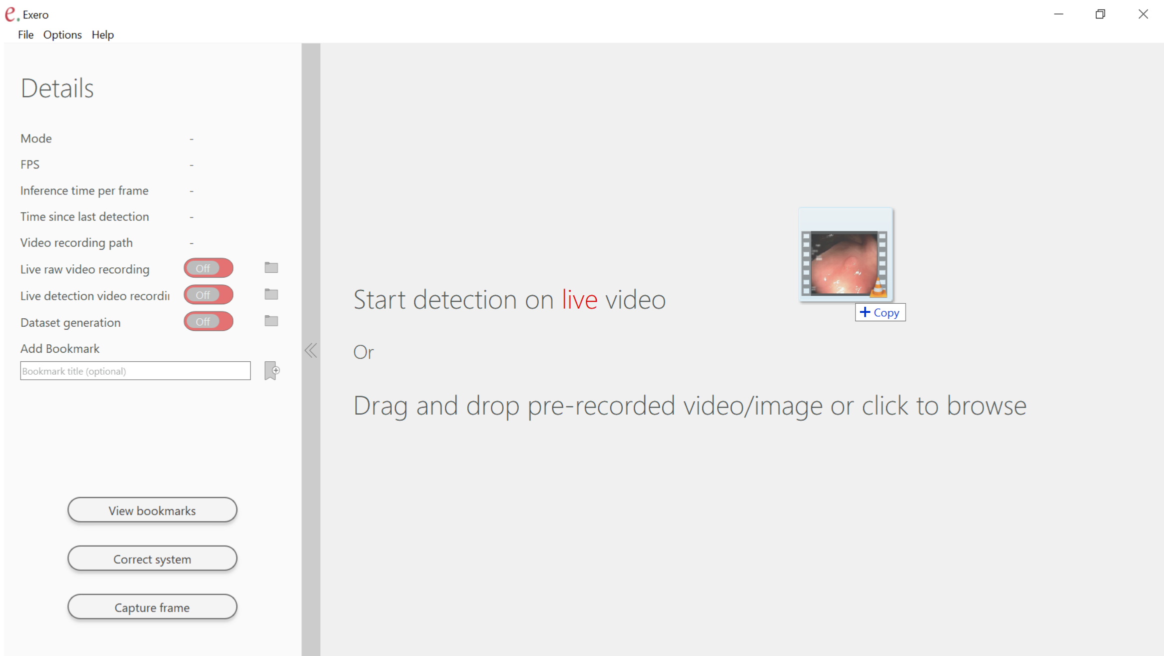

Figure 7.8: Starting detection by drag and drop video

2. After clicking Ok/Open button, the detection will start after a short delay.

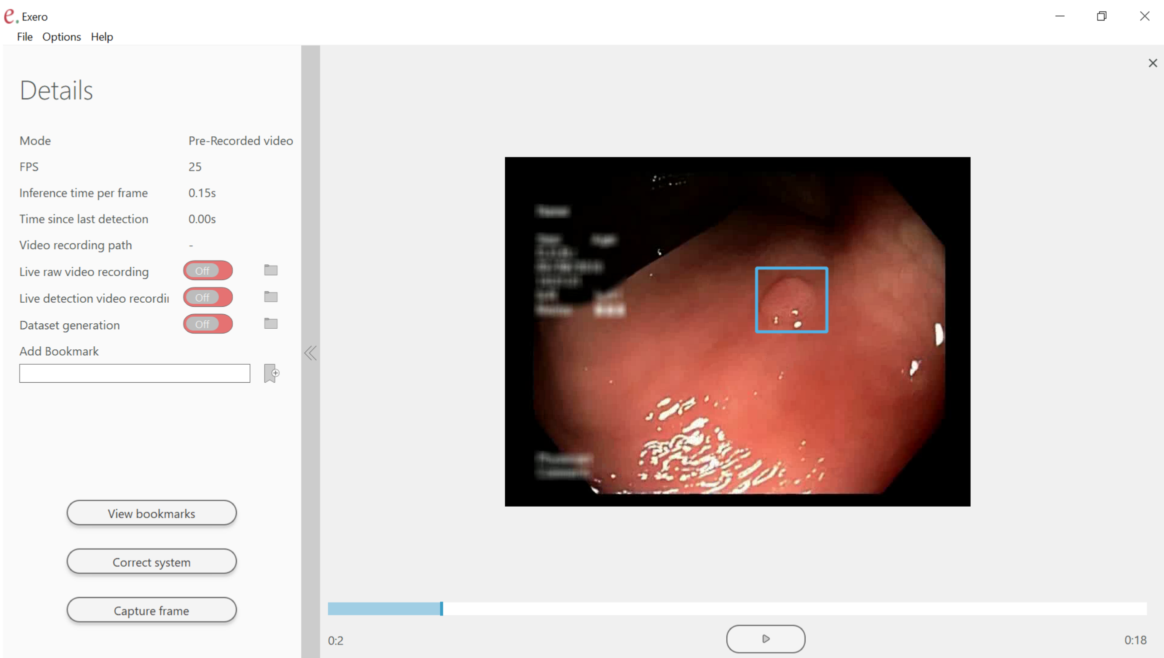

Figure 7.9: Detection Underway in Exero

3. The seek bar at the bottom shows the current position of the video as shown in the diagram above. You can also drag or click over the seek bar to change the current position. In live video, the seek bar is disabled but the current position labels works. Video can be played and pause.

4. The cross at the top left of the inner side of the screen can be pressed to close the current detection.

7.2 Exero in detail

7.2.1 Details Panel

The details panel shows information and houses quick to access features as shown in Figure 7.10. It can be collapsed to hide the information and to focus on the detection on the main screen as shown in Figure 7.11.

Details info labels

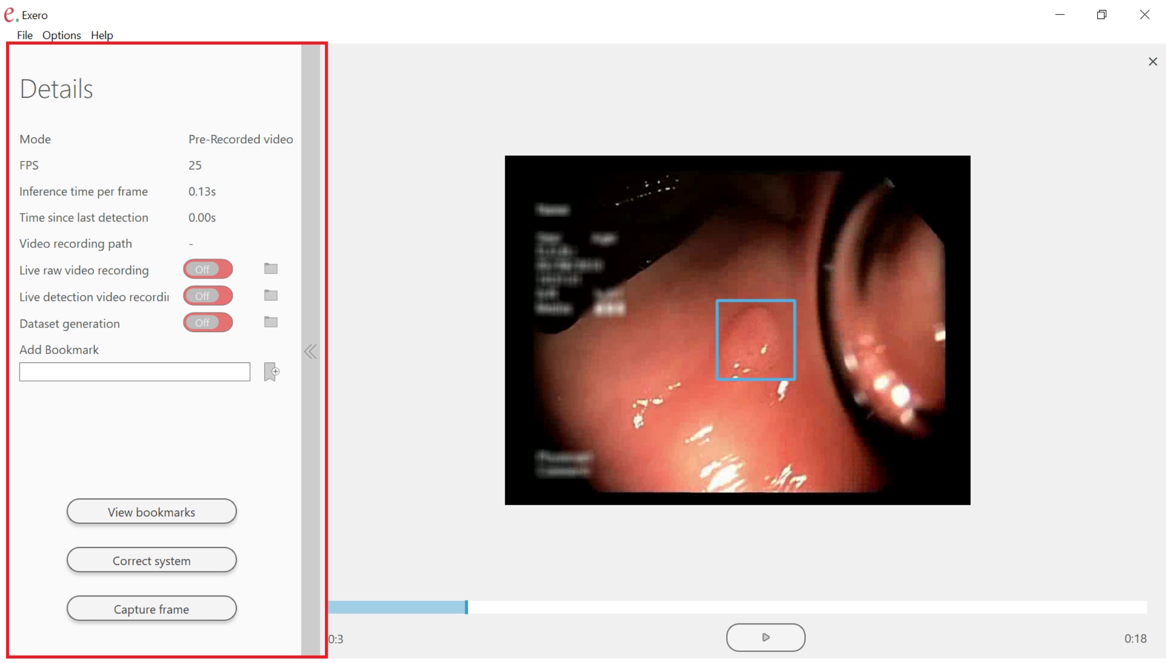

Figure 7.10: Uncollapsed side panel

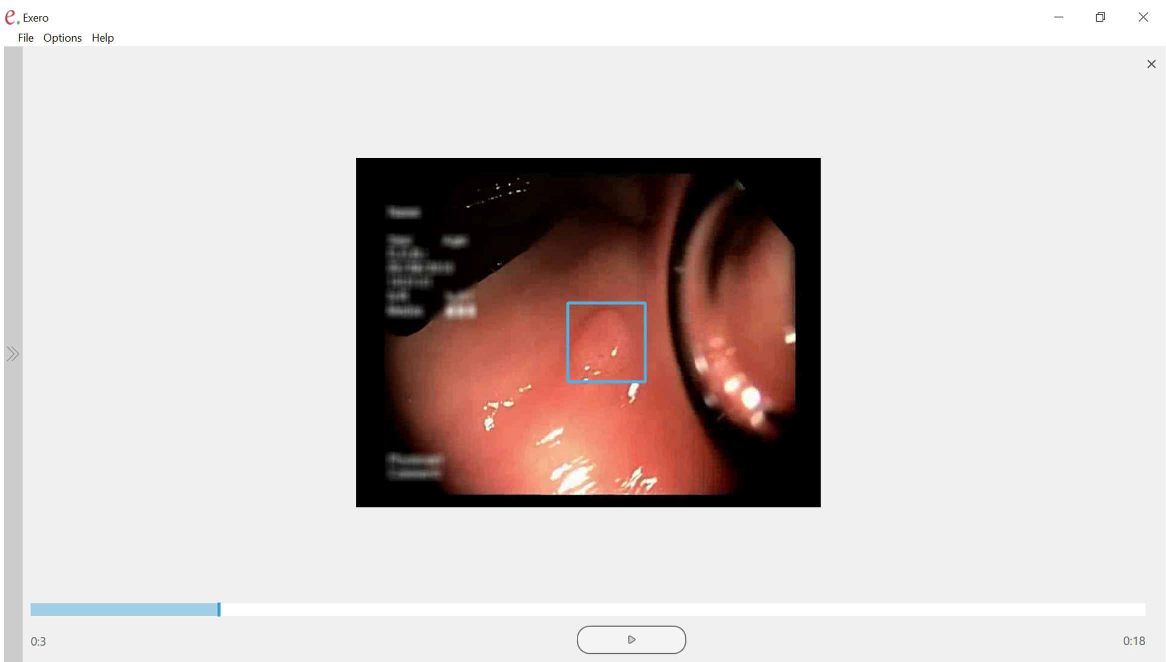

Figure 7.11: Collapsed side panel

1. **Mode** displays the type of detection currently underway. It can either be "-", "Live", "Pre-recorded Video", or "Pre-recorded Image".
2. **FPS** shows the FPS of the source.
3. **Inference time per frame** shows the amount of time it takes for the model to produce result on a single frame.
4. **Time since last detection** displays the time since the system last detected the polyp.
5. **Video recording path** shows the save path set for saving the recording.

Saving Functionality

The three saving functionalities have toggle buttons and folder-icon buttons. Toggle button provides easy, one-click access to starting and stopping the corresponding functionality. The toggle button also provides a visual indication of the current state of that functionality. The Folder-icon buttons allows to set the destination path for the file(s) being saved.

1. **Live raw video recording** saves the raw video as it is recieved without any modification, to the directory selected. The FPS of the recorded video is same as the source video, which is also displayed in the FPS label.
2. **Live detection video recording** saves the video after detection as shown on the sceen. This also includes the bounding boxes but no audio regardless of the alarm settings. The FPS of this recording video will depend on the rate at which the computer can process frames. This is calculated by using the inference time for the first frame.
3. **Dataset generation** saves the raw frames after regular intervals, which can be set in the settings.

Bookmark Functionality

User can save bookmark when pre recorded video is being used or in case of live video, the recording must be enabled. Bookmarks can be added by typing in the text field and clicking on the add bookmark icon button to add it. A success or failure message would be displayed beneath the text box. Bookmarks can be viewed by clicking on the "View bookmarks" button which will hide the details and show the bookmarks only, as shown in the figure below.

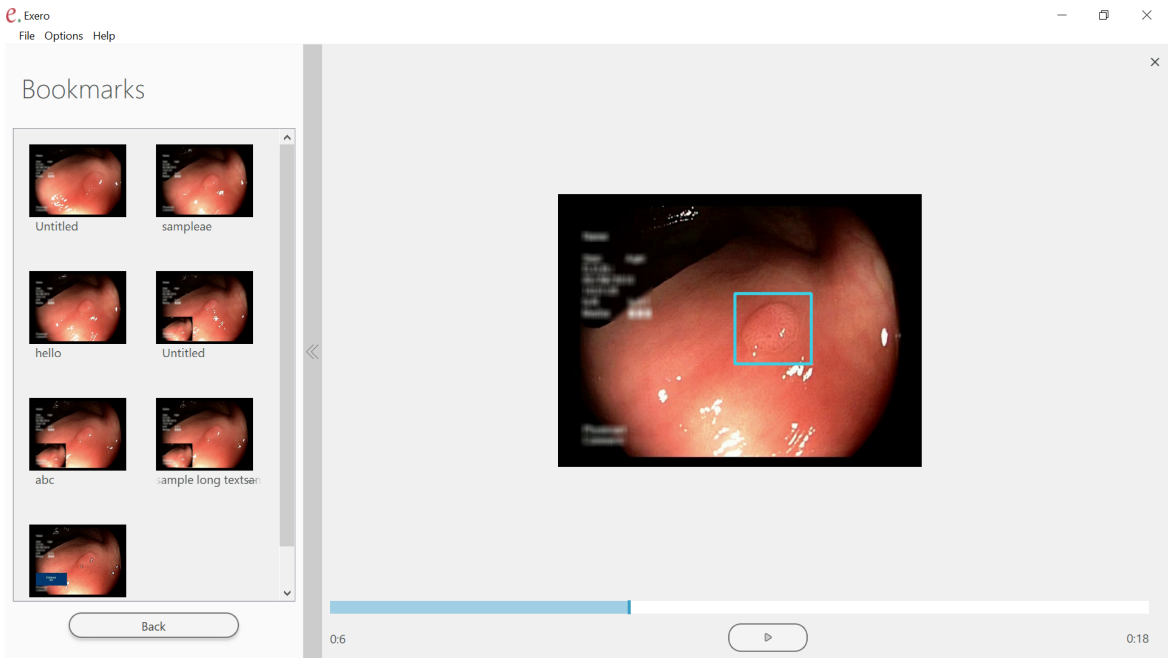

Figure 7.12: Bookmarks

Clicking on the bookmark item would jump the seekbar to that position. The bookmark file is stored in the same directory as the video file and so if the user decides to copy the recorded video to another directory, they would need to copy the bookmark file too. Bookmark file is named same as the name of the video but with and extension of txt.

Correct system Functionality

Correct System functionality provides option to user to save a frame with the result detection model provided. This is useful in cases where the user discovers that the model is providing wrong result and need to show to developers visual instance of the case, so that they can train on this and similar examples.
The raw image is saved. The name would be correctSystem_[model's detection result]_[image number].png for example correctSystem_False_2.png if its the second image and model found no polyp. The image is saved to the database generation's directory.

Capture frame Functionality

This is like a screenshot. It captures the raw image and saves it to the database generation's directory.

7.2.2 Settings

Settings could be found in the menubar's Options menu as shown below

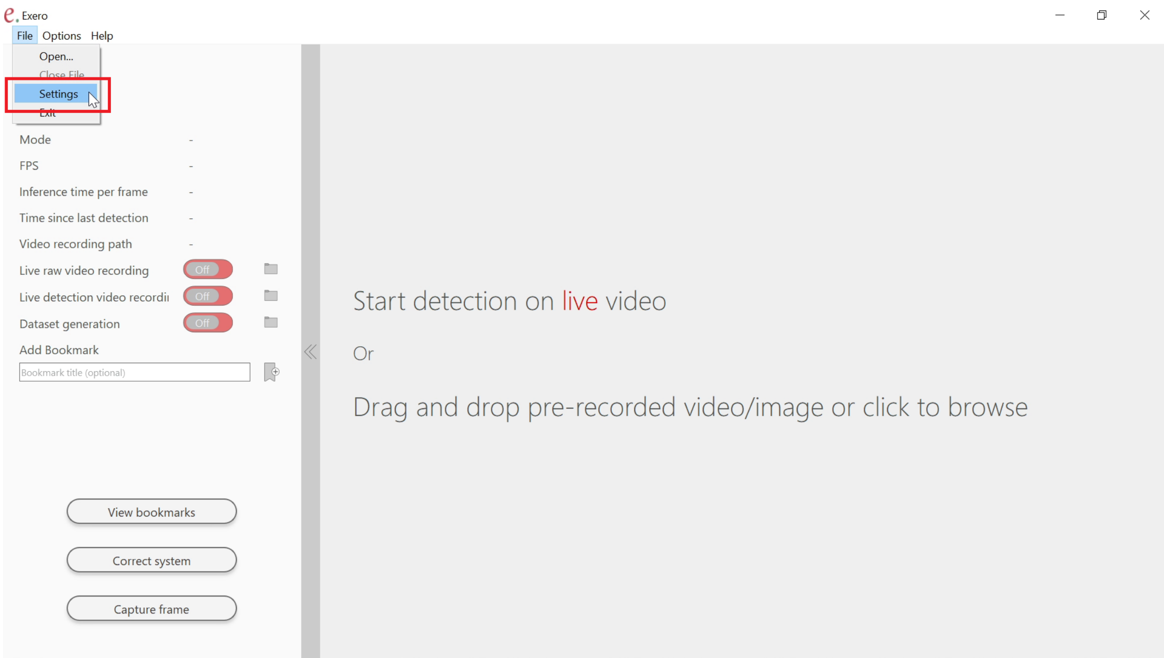

Figure 7.13: Getting to settings

The settings are divided under three sections;

General

This contains basic settings user might want to modify. These are:

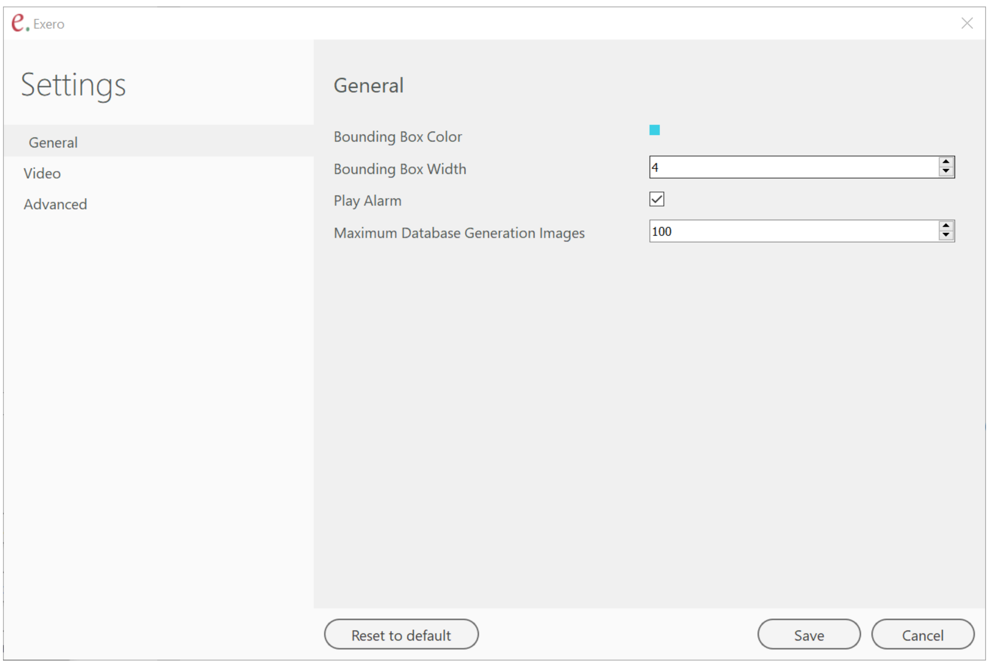

Figure 7.14: General Settings

1. Bounding box color allow user to choose the color of the bounding box.
2. Bounding box width allow user to choose the width of the bounding box's border.
3. Play alarm allows user to enable or disable the alarm sound, which is played when polyp is detected.
4. Maximum database generation images specifies the maximum amount of images that can be saved to prevent the complete utilization of disk space.

Video

This contains settings about video saving. These are:

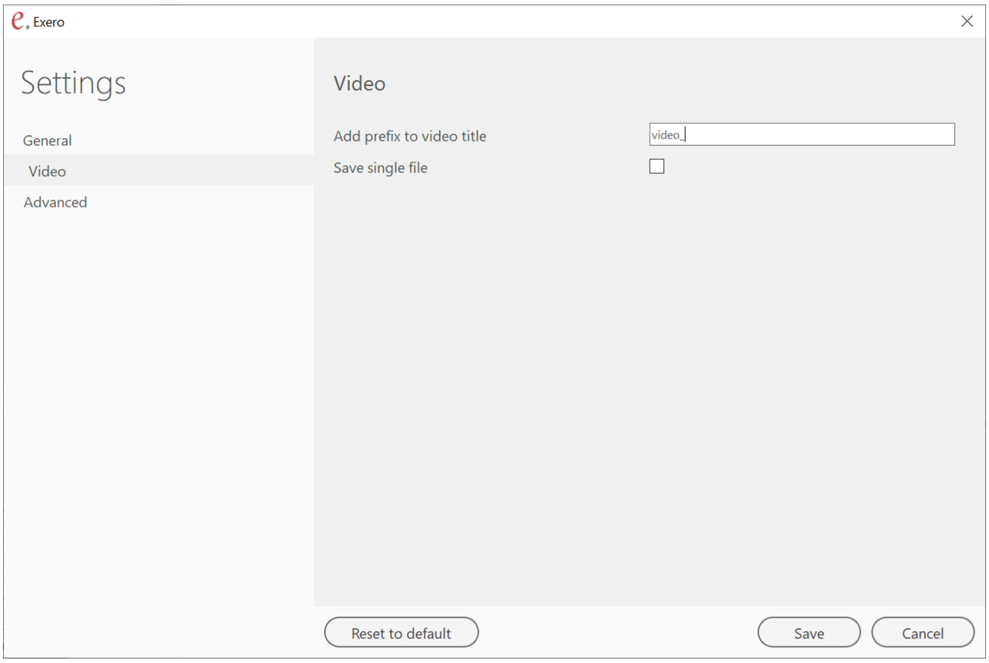

Figure 7.15: Video Settings

1. Add prefix to video title allows user to choose a prefix which would be used to save video file with the name having the provided suffix.
2. Save single file allows user choose whether to continue saving to the same video file when recording is stopped and started again or make a new video file each time it happens.

Advanced

This contains advanced settings. These are:

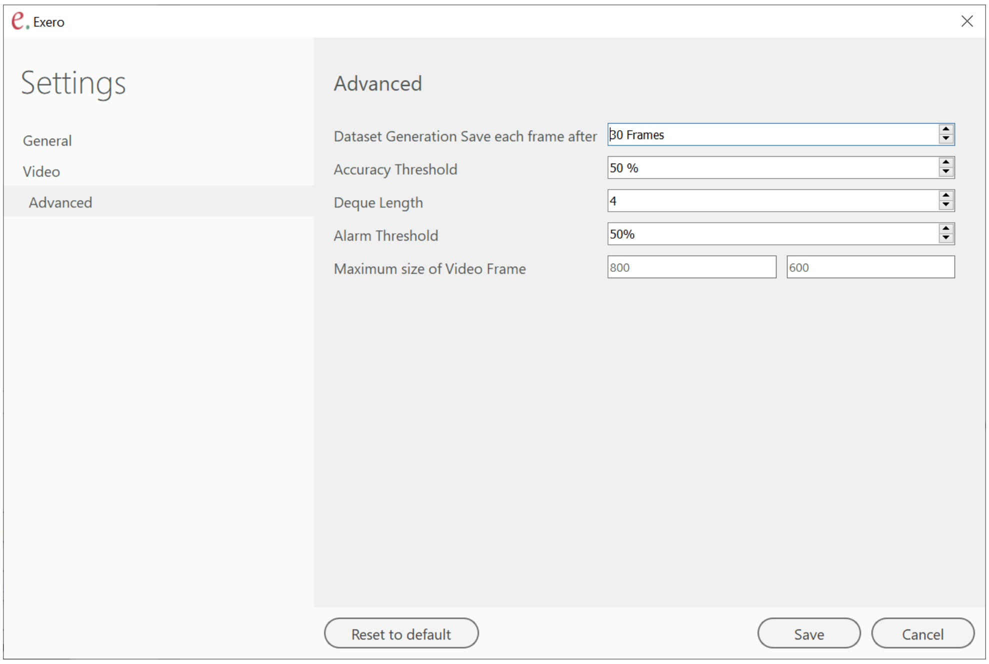

Figure 7.16: Advanced Settings

1. Dataset generation save each frame after option allow user to specify how many frames to skip before saving a frame when dataset generation is enabled.

2. Accuracy threshold is the threshold of the polyp detection.

3. Deque Length is the length of array which contains the detection results of the previous n consecutive frames. The length of array n can be specified by user. This is used in alarm to make the alarm module more robust and impervious to model detection fluctuations.

4. Alarm threshold is the threshold used by the alarm module to decide if to play alarm or not. This is applied over the average of the alarm deque. This along with the deque length n specifies how much impervious it should be.

5. Maximum size of video frame shows the size of the video port shown at the main screen.

Reset to default

This option resets the values to the default values.

Save

This saves any changes made by user.

Cancel

This discards any unsaved changes and close the window.

Chapter 8

Conclusion & Future Enhancements

Through this project we learned that the User Interface and User Experience is very important thing to consider especially if the application is intended for a place like hospital.

Another thing we learned is that using a pretrained model and using transfer learning to train model is a good and easy way to get good performance. Augmenting the dataset also produce good results.

In future, a database should be added to store the patients basic data and reference the video recorded and images captured to the specific patient instance easily. Another thing that could be added is that correct system should save another image with a bounding box so as to show where the system detected polyp or not. A feedback window could also be incorporated to allow user to provide easy feedback right from the application.

Appendix A

Poster

Figure 8.1 shows the poster of the project.

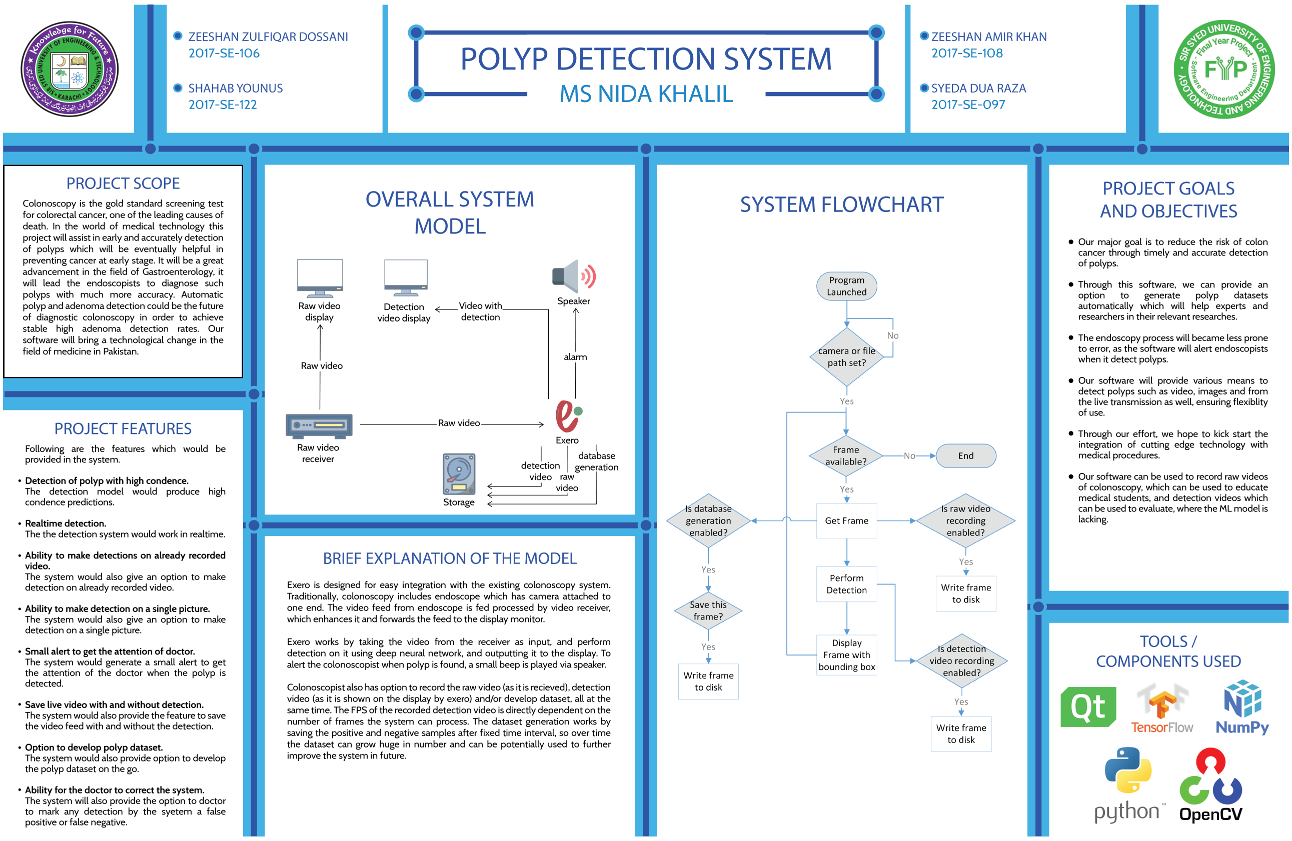

Figure 8.1: Poster of Polyp Detection System

Standee

Figure 8.2 shows the standee of the project.

Figure 8.2: Standee of Polyp Detection System

Brochure

Figure 8.3 shows the front side of the brochure.

Figure 8.3: Brochure of Polyp Detection System - Front

Figure 8.4 shows the back side of the brochure.

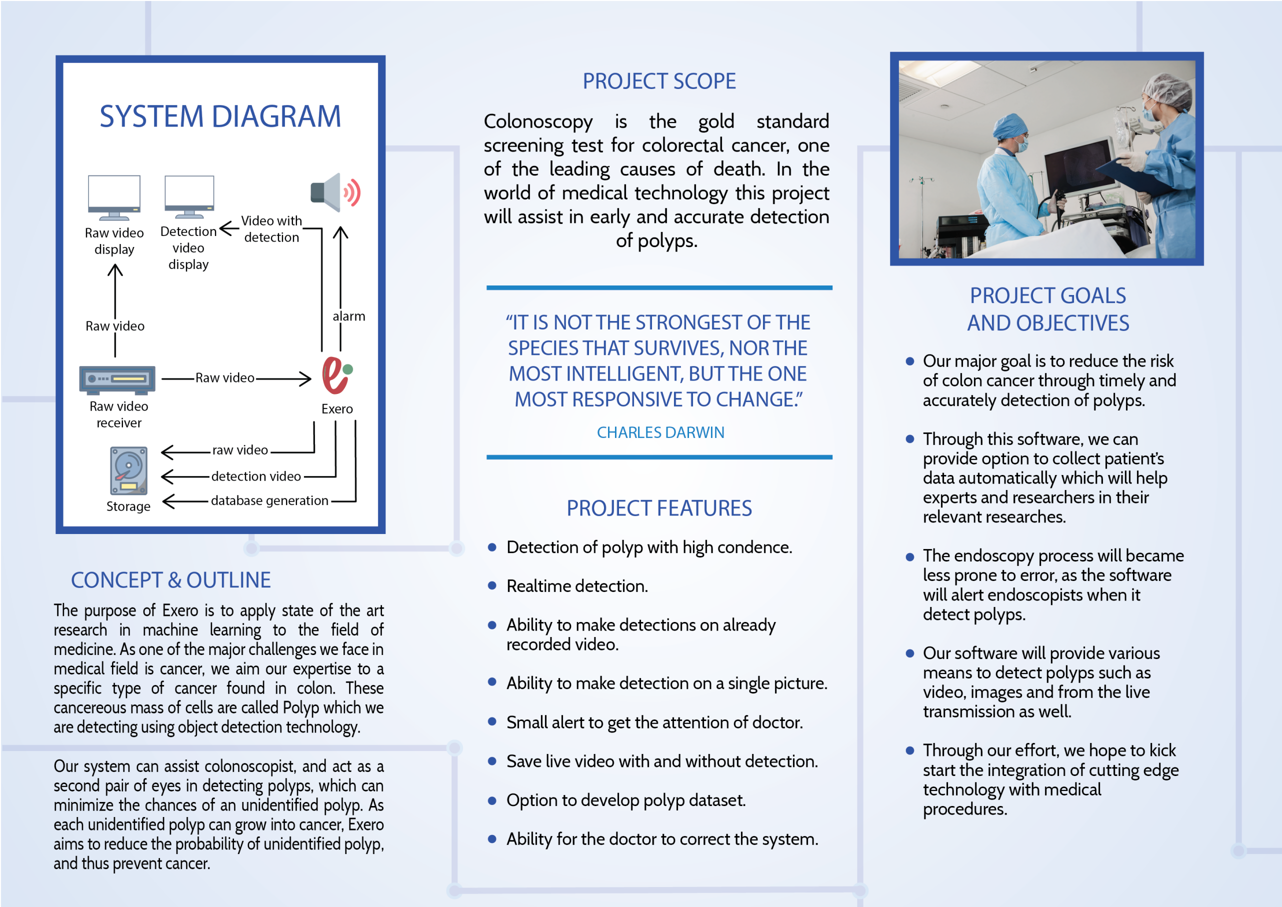

Figure 8.4: Brochure of Polyp Detection System - Back

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Remarks and Comments

Polyp Detection System using Machine Learning

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***Abstract*—This report compiles and presents the work performed during the period of Final Year Project on Polyp Detection System. With aim to reduce the misclassification of polyps by doctors, we developed a software to assist doctors in the task. Our major effort went towards making sure to strike a perfect balance between ease of use, intuitiveness and advanced functionalities. We reviewed several research papers and compiled the findings and draw insights from them. In-detail diagrams are also shown in the Technical documentation section which helps visualize the inner workings of the system. The tradeoffs and considerations made through out the project are explained in the methodology.**

I. Introduction

Cancer is one of the leading causes of deaths. It is a form of non-communicable disease. Cancer screening tests are performed in which the tumors are visually identified and removed. The most common of these tests is Colonoscopy. This procedure is of paramount importance as these tumors can grow into cancer if left untreated. Due to fatigue, the operator or doctor can miss the polyp, especially those which are small in size, but present the risk of cancer nonetheless. therefore we aim to exploit the recent progress in deep learning and computer vision to enhance the procedure.

This system is highly practical as it doesn't require the operator any extra time or special training. It can also be integrated with any existing equipment. The monetary cost is minimal and the system provides great value in terms of human lives.

Our major goal is to reduce the risk of colon cancer through timely and accurately detection of polyps. The endoscopy process will became less prone to error, as the software will alert endoscopists when it detect polyps. Our software provided various means to detect polyps such as video, images and from the live transmission as well. Through this software, we provided an option to collect patient's data automatically which will help experts and researchers in their relevant researches. All the data was stored locally so as to prevent the concern for user's data protection. Through our effort, we hope to kick start the integration of cutting edge technology with medical procedures.

II. Dataset

The dataset Kvasir-SEG was used[1] which contains 1000 images of polyps. The dataset was subjected to auto-augmentation to increase the dataset size and making the resulting model more robust to the real life performance.

III. Model

The model Single-Shot Detector(SSD)[7] was chosen, and was trained using Transfer Learning. For training purposes, the Tensorflow Object Detection API[6] was utilized which provided fast iteration. The model was trained on Google Colaboratory. SSD was chosen because of its shear ability to produce quick inferences. This is very important as we aim to use the model in live setting.

IV. Methodology

A. *Design phase*

The proposed solution to the problem described above is the use of advancements in the field of deep learning to develop an intelligent system which can detect polyps by using object detection algorithms. The colonoscopy uses an endoscope which has a camera. During the procedure, the doctor views the live video on a monitor. Our system would replicate the video, pass it into our system and display the output on a monitor. This setup is ideal as it would require minimum interaction of operator and the alarm/alert would get the attention of the doctor only when required. It also doesnt́ require any special training and the learning curve is also minimal.

The system UI is made with great care to make sure that color scheme doesn't cause eye fatigue in long term use. Using the system is straight forward too; after Launging the program, the user is presented with three ways to start the detection, by live video, recorded video, or recorded picture. Live video further asks to choose the camera they want to use. After selection, the detection starts rightaway and the video is shown in the center of the screens. User are also presented with options they might need on the left hand side in a collasible panel. This makes the user experience better but allowing the user to get the options out of the way and access them back with a single click. All the main features are presented in this side panel which makes it super easy to use.

When polyp(tumor) is detected, a sound alert is played to catch attention of the doctor. This can be turned off incase doctor founds it distracting. An algorithm is designed and implemented to make sure that the sound is played only when

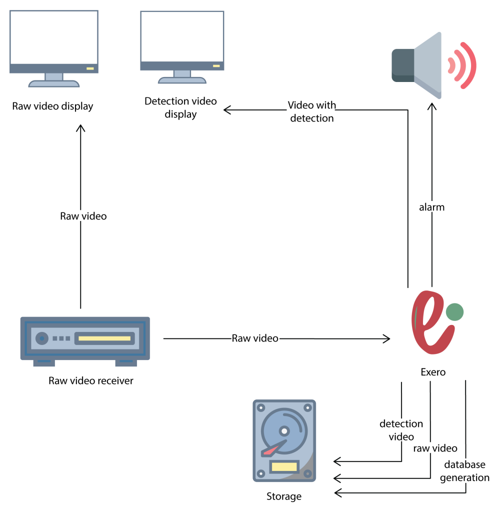

Fig. 1: System Diagram

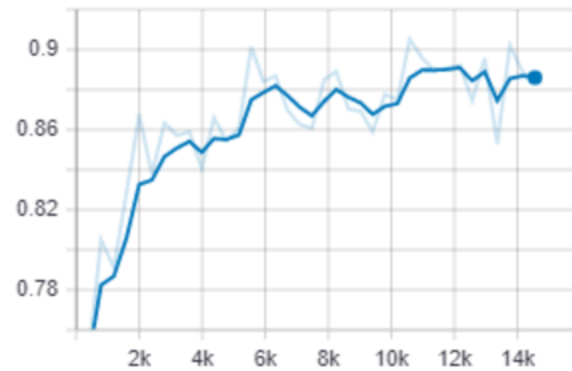

Fig. 2: Accuracy of model

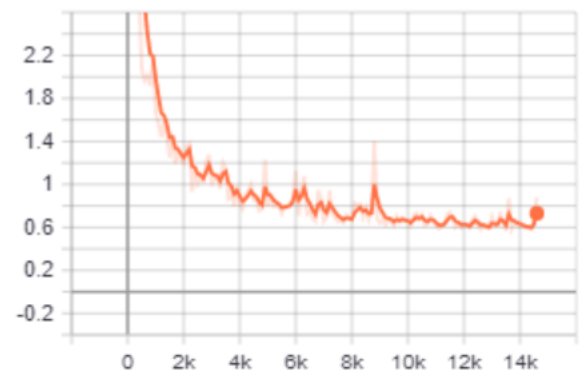

Fig. 3: Loss throughout the training

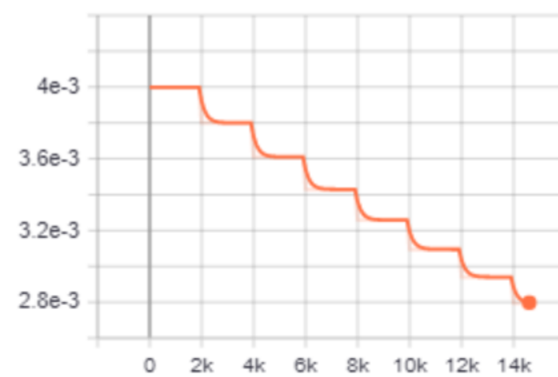

Fig. 4: Learning rate with decay rate 95 and step 2000

the model is really sure of the polyp, and to be able to brace if model incorrectly doesn't detect frame.

B. Implementation phase

Python was the language used to develop the system as it is very easy to use and the popular machine learning libraries have great python support. For the machine learning part of the application, we used Tensorflow and its open source Tensorflow Object Detection API to train our model using transfer learning. Numpy was used for handling the image data. PyQt is used to develop a UI. QThreads from PyQt were utilized to make the system multithreaded and responsive. OpenCV was also used to handle the video stream. The end result is a multi-threaded python desktop application.

V. Model Development

The model chosen was SSD Inception v2 [7] as it has a good inference time and can be used in realtime. Tensorflow Object detection API was utilized to transfer learn on this model using different hyperparameters. The comparison of these is shown in the table I. The dataset Kvasir-SEG was used [1] which contains 1000 images of polyps. The same dataset was used on all the variants of model. The findings are as follows

- We found that increasing the learning rate reduced the accuracy.
- Adam optimizer didn't perform well.
- AutoAugmentation was instrumental in getting good performance as the dataset was quite small.
- Adding dropout also helped avoid overfitting.

The second model in the table I was selected for final use in the application. Its accuracy is given in figure 2 , loss in figure 3 , and learning rate in figure 4.

VI. Features

Making sure that the features provided in the software compliments the work of an endoscopist and is actually very important. Following are the features which we provided in the system:

- **Detection of polyp with high confidence.**
  The detection model would produce high confidence predictions.
- **Realtime detection**.
  The detection system would work in realtime.
- **Ability to make detections on already recorded video**.

TABLE I: Comparison of different model hyperparameters

Models	mAP@.50IOU	Loss
SSD Transfer Learning 25000 epochs, rmsProp, dropout90, lr0.004	**0.904**	1.17
SSD Transfer Learning 15000 epochs, rmsProp, dropout90, autoaugment, lr0.004, step 2000, decayRate95	**0.904**	**0.667**
SSD Transfer Learning 25000 epochs, adam, dropout90, autoaugment, lr0.004, step 2000, decayRate95	0.782	0.88
SSD Transfer Learning 10800 epochs, rmsProp, dropout90, autoaugment, lr0.045, step 2, decayRate94	0.861	3.37
SSD Transfer Learning 12914 epochs, rmsProp, dropout90, autoaugment, lr0.045, step20, decayRate94, gradClip2.0	0.887	1.43

The system would also give an option to make detection on already recorded video.

- **Ability to make detection on a single picture**.
  The system would also give an option to make detection on a single picture.
- **Small alert to get the attention of doctor.**
  The system would generate a small alert to get the attention of the doctor when the polyp is detected.
- **Save live video with and without detection.**
  The system would also provide the feature to save the video feed with and without the detection.
- **Option to develop polyp dataset**.
  The system would also provide option to develop the polyp dataset on the go.
- **Ability for the doctor to correct the system**.
  The system will also provide option to the doctor to mark any detection by the model, a false positive or false negative.
- **Monitor DPI aware adjustment**.
  The system would automatically scale up or down all the UI according to the DPI of the screen, ensuring consistent User Interface accross different sized monitors.
- **Save Bookmarks**.
  The system provide feature to save the current position of video and a text as a bookmark.

VII. Similar Studies

There have been several studies over time mainly focusing on the impact of using such a system in medical environment. Pu Wang et al. in their paper [2] developed their algorithm was trained on data from 1,290 patients and validated on 27,113 images containing at least one polyp from 1,138 patients, on a public dataset of 612 images, on 138 colonoscopy videos with polyps and 54 full videos of colonoscopy without polyps. Their algorithm successfully acheived 25 frames per second. Yuichi Mori et al. in their paper [3] provided arguments in support of need and benefits of the computer aided diagnosis in coloscopy. Pu Wang et al. in another study [4] provided the results of a clinical trial about the use of this kind of system. They found that the system resulted in increased detection rate by the doctors. Nadim Mahmud et al. in their research paper [5] presented their findings and arguments about the effectiveness and benefits of using computer vision and augmented reality in gastrointestinal endoscopy.

VIII. Conclusion

Through this project we learned that the User Interface and User Experience is very important thing to consider especially if the application is intended for a place like hospital.

Another thing we learned is that using a pretrained model and using transfer learning to train model is a good and easy way to get good performance. Augmenting the dataset also produce good results.

In future, a database should be added to store the patients basic data and reference the video recorded and images captured to the specific patient instance easily. Another thing that could be added is that correct system should save another image with a bounding box so as to show where the system detected polyp or not. A feedback window could also be incorporated to allow user to provide easy feedback right from the application.

Acknowledgment

First of all, we would like to thank Almighty Allah who gifted us with the ability to think and reason. Secondly, we would like to express our special thanks of gratitude to our Project Internal Advisor Ms. Nida Khalil who guided and supported us throughout our project. We would also like to thank Sir Tauseef Mubeen for his unwavering support and time. We also want to show our gratitude to Dr. Mirza Muhammad Ali who gave their time to guide us in our project and Mr. Humza Sheikh for his suggesions to improve the UI. We are also grateful to parents and siblings who supported and motivated us to do our best.

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