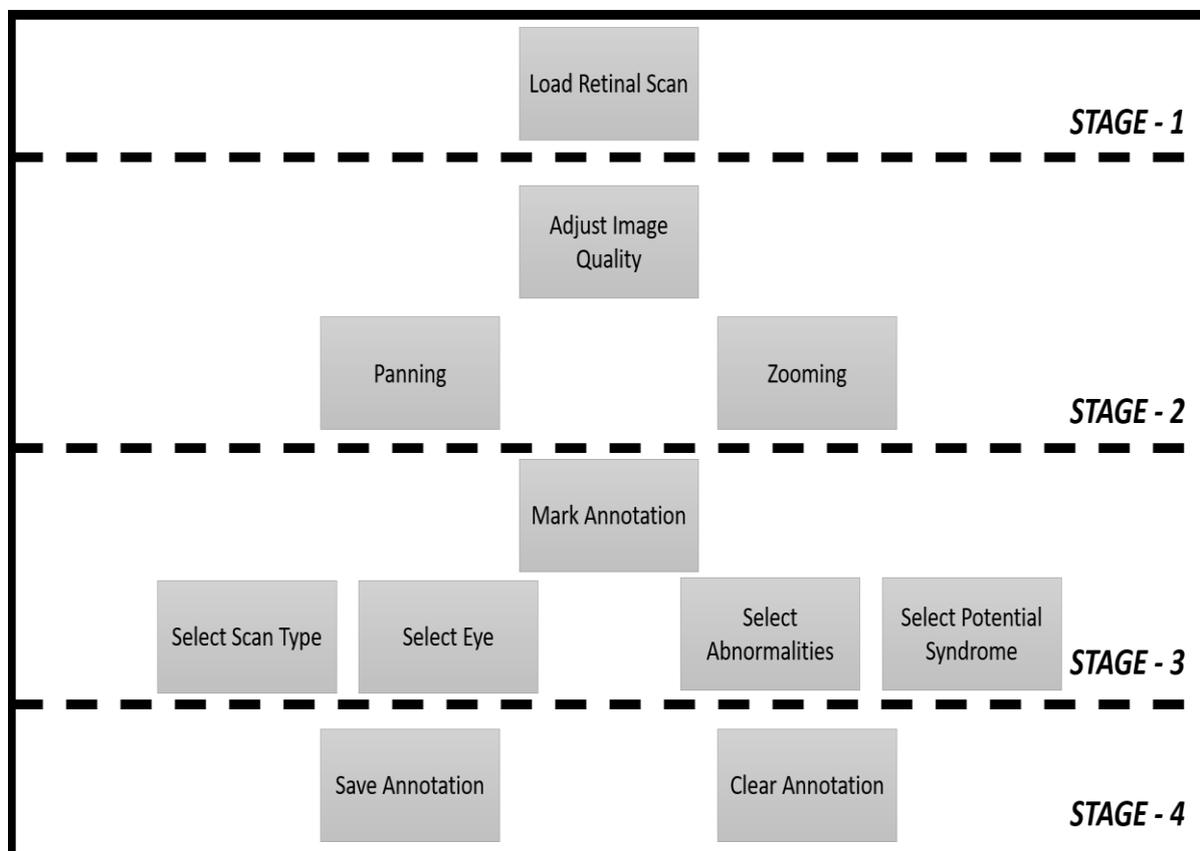


Progress Report for 1st Quarter, May-July 2017

OCT Image Analysis System for Grading and Diagnosis of Retinal Diseases and its Integration in i-Hospital

Milestone 1: Designing Annotation tool extraction algorithms into high level Language

The aim of this milestone was to develop a tool for annotation of fundus and OCT images to generate a standard dataset. We developed BIOMISA RETINAL IMAGE ILLUSTRATOR. BIOMISA Retinal Image Illustrator is an application that is specifically designed to annotate retinal diseases and their complications from digital fundus and optical coherence tomography (OCT) images. The application is first of its kind to provide user the capabilities to mark retinal abnormalities along with highlighting potential retinal syndromes. The user friendly graphical interface of the application allows medical specialists and researchers to comfortably adjust the contents of the observed images through pan and zoom. Apart from this, the application has powerful in-built image enhancement capabilities that allows users to improve the quality of the candidate retinal scan. Upon completing the annotations, the application allows users to save their work through a 'single click'. The detailed application workflow is shown below:



Application Workflow

Deliverable: Desktop application for Annotations and dataset generation

Results: The application is fully developed and has gone testing phase as well. Now we are annotating datasets using this tool. **A detailed user manual is attached separately.**

Milestone 2: Collection of OCT images and get the dataset annotated by ophthalmologist

A number of fundus image databases are available online for public use and research purposes but as far OCT image analysis is concerned, no such specific datasets are available. The aim of this milestone was to develop our own dataset of OCT with annotations marked by doctors. Then we will make this dataset publicly available.

BIOMISA Retinal Image Database for Macular and Ocular Syndromes

We present a complete dataset suite that incorporates both retinal fundus and optical coherence tomography (OCT) imagery for the quantification of retinal disease patterns. The dataset is primarily designed for researchers to test the efficiency of fully automated clinical decision support systems (CDSS) that are being developed to diagnose and mass screen various complications of retinal pathology. The dataset contains detailed annotations for both fundus and OCT analysis where each annotation is characterized according to the respective underlying retinal morphology. Apart from this, the dataset is unique in its way that it includes both retinal fundus as well as OCT B-scans and C-scans, giving the capabilities of correlating cross-sectional retinal pathology with prominent fundus anomalies for accurate and objective diagnosis.

A. Image Acquisition

The proposed dataset has been acquired from Armed Forces Institute of Ophthalmology (AFIO), Rawalpindi, Pakistan. The data acquisition phase was carried out under the strict observation of multiple expert ophthalmologists. Apart from this, the annotations were carried out individually by each ophthalmologist based on their knowledge and expertise, in an isolated zone. All the patients that were involved in dataset collection were selected after complete medical examination and their clinical history. Patients with normal examination results are categorized as healthy and images acquired from them are labeled as normal. The nominal age limit for the candidates were 25 to 80 years where the ratio of males and females were proportionally balanced.

Both fundus and OCT images are acquired using TOPCON 3D OCT 2000 machine after proper eye dilation to get a good visualization of internal retina. Fundus images are centered on optic disc and macular regions, with the dimensions of 2032 x 1934 pixels. OCT imagery are characterized as B-scans and C-scans where B-scans are acquired with the resolution 951 x 456 pixels and C-scans contains 128 frames where each frame has a resolution of 760 x 576 pixels. Fundus and OCT B-scans are stored in JPEG uncompressed images while OCT C-scans are stored in WMV format with 15 frames per second. Images with poor illumination, unclear information and improper capture were discarded. Table 1 summarizes the proposed dataset.

Table 1: Dataset Summary

Dataset	Fundus		OCT		OCT	
			B-scans		C-scans	
	Healthy	Diseased	Healthy	Diseased	Healthy	Diseased
Resolution	2032 x 1934 pixels	2032 x 1934 pixels	951 x 456 pixels	951 x 456 pixels	128 frames of 760x 576 pixels	128 frames of 760x 576 pixels
Maculae Centered	10	10	10	11	9	10
Optic Disc (OD) Centered	19	25	19	25		
Presence of Exudates and Cysts		6		7		6
Presence of Hemorrhages		2				
Presence of Drusen and RPE Atrophy		4		4		4
Cup to Disc Ratio	12	14	12	14		

The dataset contains 64 fundus scans (20 maculae centered and 44 OD centered) and 2497 OCT B-scans (2453 are of macular region and 44 are of OD region). Out of these 2497 B-scans, 2432 B-scans are embedded into 19 C-scans of 128 frames. To the best of our knowledge, this dataset is anonymous and we have removed all the patient affiliations from the dataset. Apart from this, 29 out of 64 fundus images contains healthy pathology while 35 images contain retinal anomalies, which are further characterized into exudates, hemorrhages and drusen etc. Similarly, 1181 OCT B-scans contains no abnormal symptoms while remaining 1316 contains cysts, RPE atrophic profile and glaucoma etc. Figure 1 shows two randomly selected diseased fundus scans from the proposed dataset that depicts the retinal abnormalities.

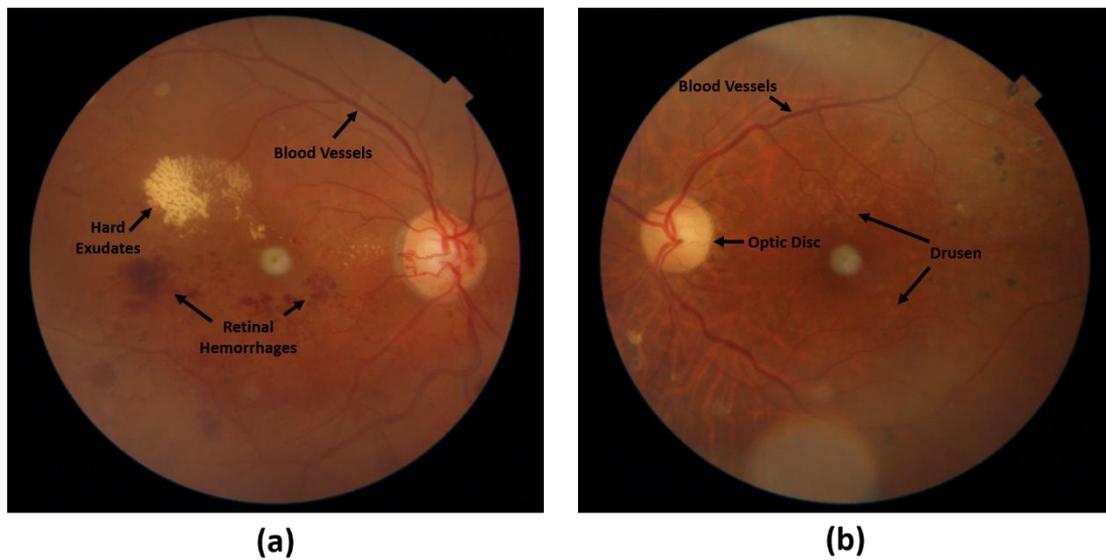


Figure 1: Abnormal pathological symptoms on fundus images reflecting different types of retinal syndromes

Figure 2 shows a randomly selected OCT B-scans from the proposed dataset that depicts the early cross sectional retinal anomalies.

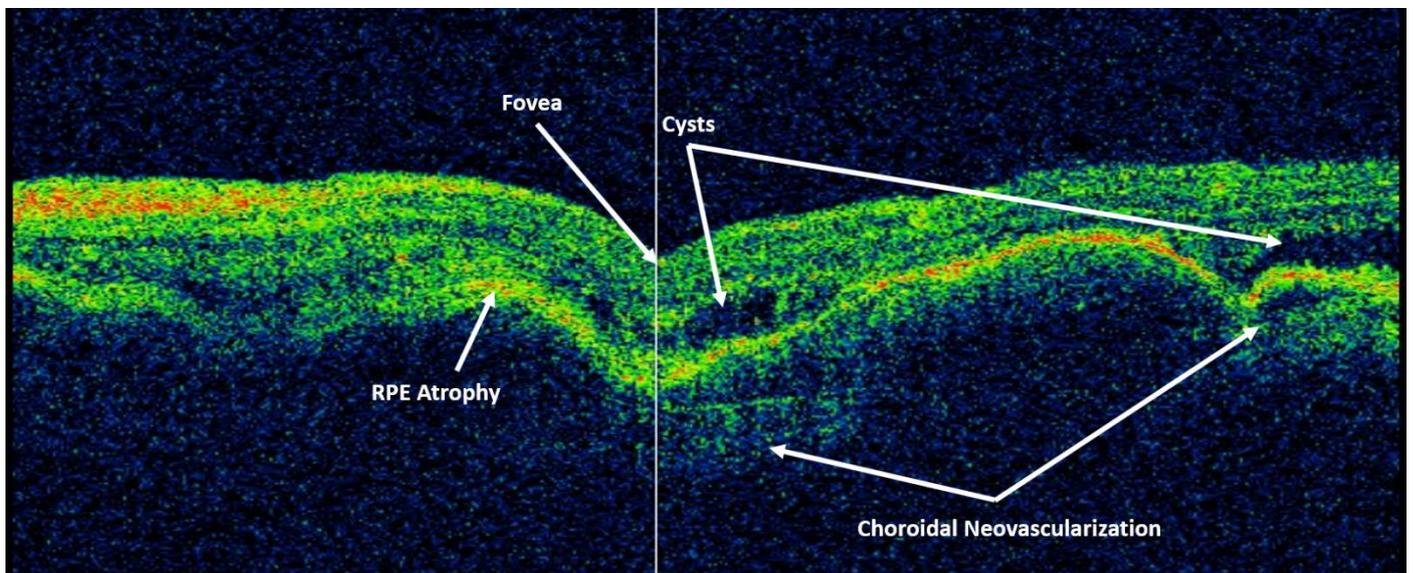


Figure 2: Abnormal pathological symptoms on OCT B-scan reflecting different retinal syndromes

The dataset is targeted for diagnosing different pathological variations within human retina. Also, the proposed dataset contains detailed annotations for different disease patterns, marked by multiple expert ophthalmologists. To the best of our knowledge, the proposed dataset is first of its kind in providing detailed annotations for different pathological conditions that appears in various retinal diseases on both fundus and OCT imagery. In OCT images, the dataset contains detailed annotations for up to nine retinal layers in both healthy and diseased pathology as shown in Figure 3. This is apart from all the other disease specific annotations which are also present within the proposed dataset. Similarly, for fundus imagery, the dataset contains detailed annotations for drusen, hemorrhages and hard exudates. For OD centered fundus scans, we have provided the mean cup to disc ratio (CDR) calculated by expert graders for both healthy and glaucomic pathology.

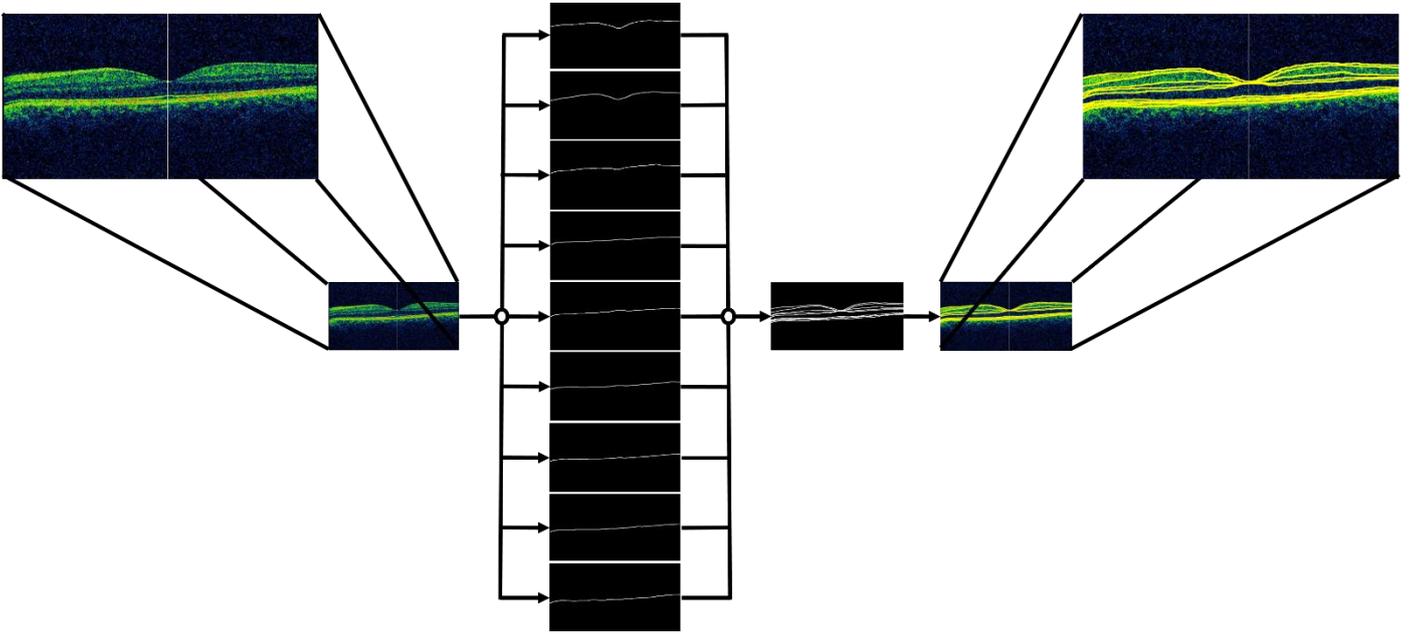


Figure 3: Marked annotations of up to nine retinal layers from healthy OCT B-scan. From top to bottom, the extracted layers are: Inner Limiting Membrane (ILM), Retinal Nerve Fiber Layer (RNFL)-Ganglion Cell Layer (GCL), Inner Plexiform Layer (IPL)-Inner Nuclear Layer (INL), INL-Outer Plexiform Layer (OPL), OPL-Outer Nuclear Layer (ONL), ONL-Inner Segment (IS), IS-Outer Segment (OS), OS-Retinal Pigment Epithelium (RPE), Bruch's Membrane (BrM)

B. Data Annotations

The dataset contains 64 fundus images and 2497 OCT B-scans of both eyes, annotated by four expert ophthalmologists. All the four ophthalmologists annotated the dataset separately based upon their domain expertise through BIOMISA Retinal Image Illustrator software. These annotations are used for the characterization of different retinal diseases like Macular Edema (ME), Exudative/ Non-Exudative Age related Macular Degeneration (AMD) and Glaucoma. Moreover, there are many images in the proposed dataset that contain multiple pathological abnormalities. One of such cases is shown in Figure 4. The proposed dataset is designed in such a way that it contains separate annotations for each abnormality within the candidate images. These annotations allow researchers to perform automated analysis on the desired pathologies. Apart from this, the proposed dataset is characterized according to different retinal pathological conditions where each disease contains their own specific annotations, as discussed below.

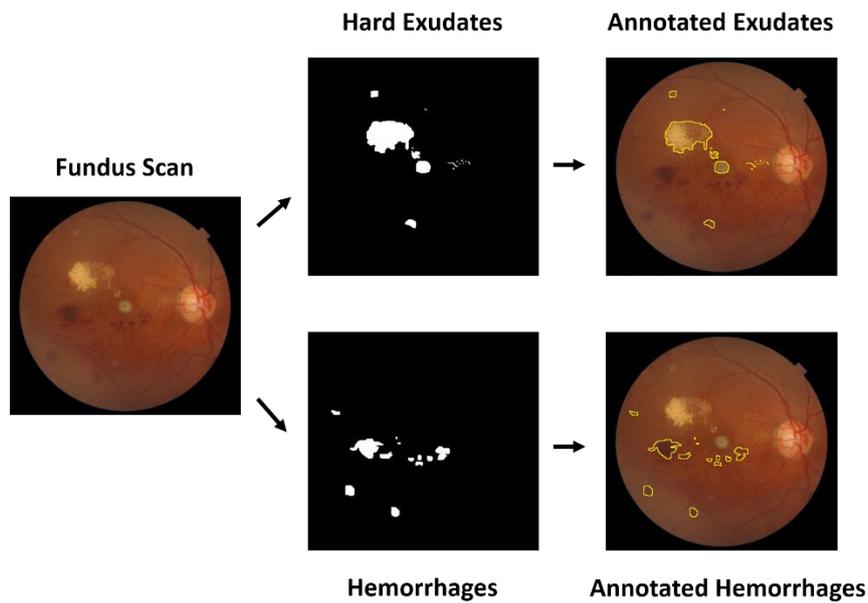


Figure 4: A fundus scan containing exudates and retinal hemorrhages. Each abnormality has a separate annotation map in the proposed dataset

Hard Exudates and Cysts:

ME is normally characterized from fundus images by checking the presence of hard exudates. Hard exudates appear on the fundus image due to blood fluid leakage within intra-retinal pathology. These fluids form irregular cysts within the retinal layer, observed through cross-sectional OCT scan. The proposed dataset contains the annotations of hard exudates from fundus photographs and cyst morphology from OCT B-scan. A randomly selected fundus and OCT scan containing ME pathological symptoms is shown in Figure 5.

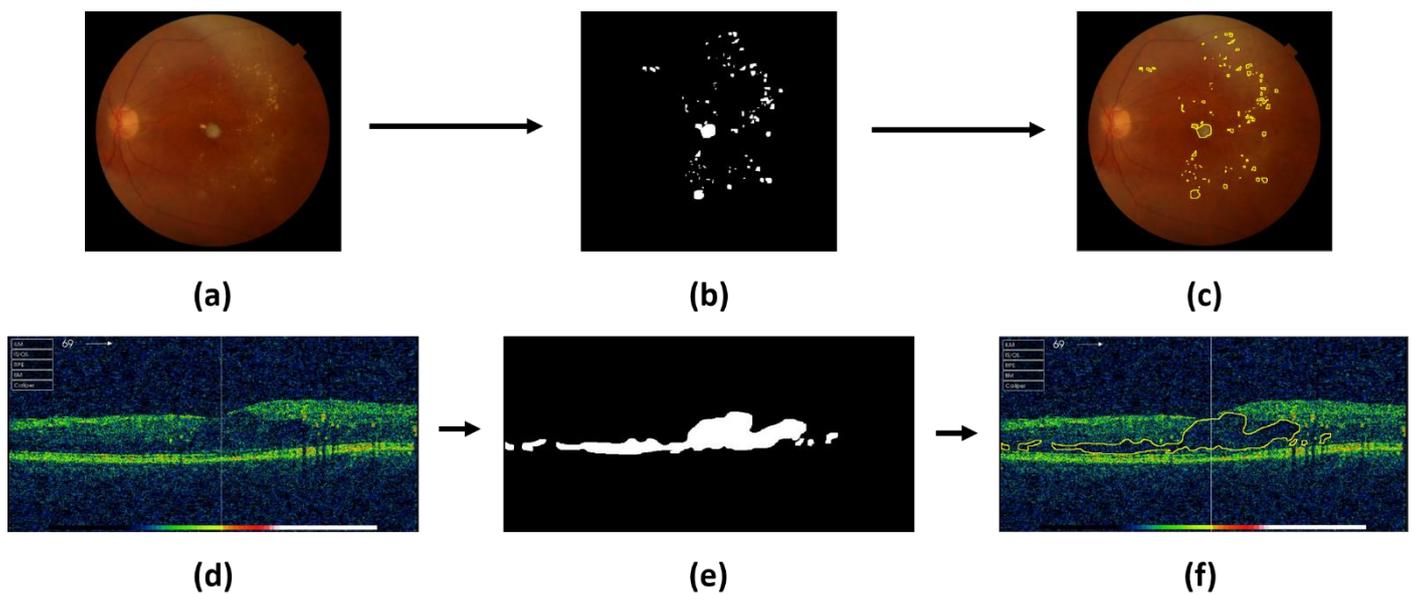


Figure 5: Retinal scans (a) original fundus image, (b) annotation map depicting exudates, (c) extracted exudates marked on (a), (d) original OCT B-scan, (e) annotation map containing cyst pathology, (f) extracted cysts are highlighted on (d)

Drusen and RPE Atrophy:

AMD is mainly characterized by seeing the presence of drusen on the fundus scan. From OCT B-scan, RPE atrophic profile highlights non-exudative or dry AMD. Exudative or wet AMD is an advanced stage of AMD in which cysts and exudates also appears due to fluid leakage. Figure 6 shows one of the randomly selected AMD positive subject from the proposed dataset.

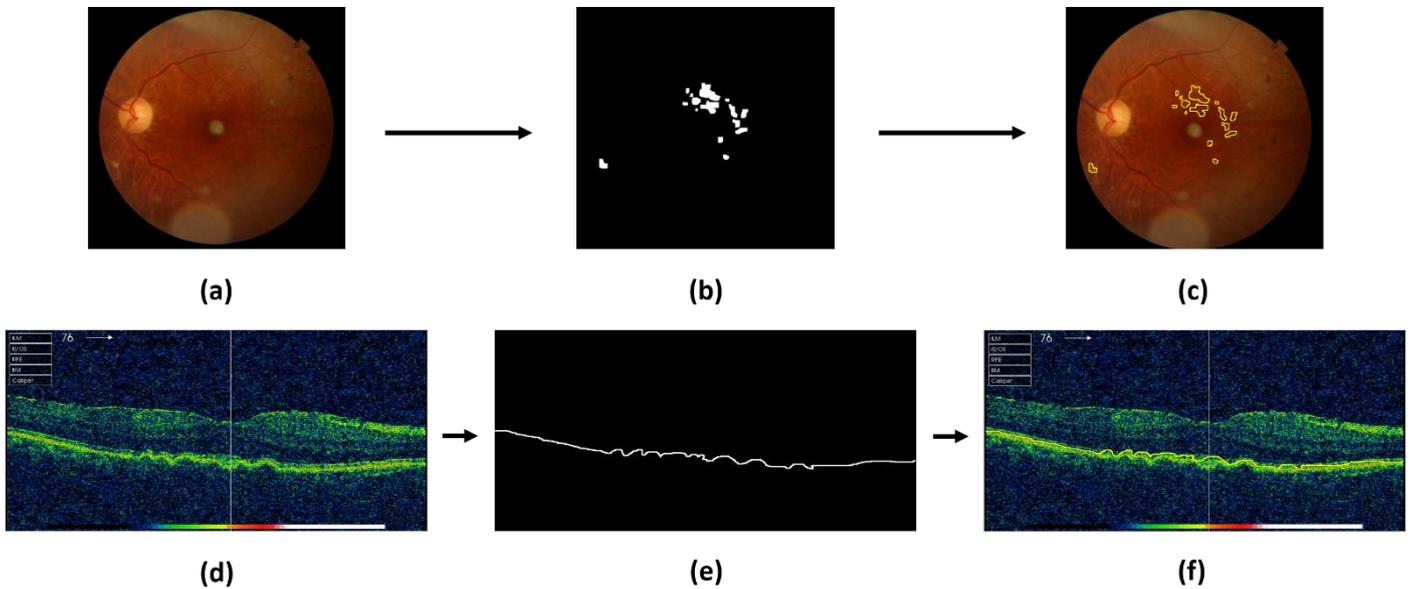


Figure 6: Retinal scans (a) original fundus image, (b) annotation map depicting drusen, (c) extracted drusen marked on (a), (d) original OCT B-scan, (e) annotation map containing RPE atrophy, (f) extracted RPE profile is highlighted on (d)

Cup to Disc Annotations:

Glaucomic patients are often identified by measuring CDR from both OD centered fundus and OCT imagery. The proposed dataset contains 44 OD centered fundus scans and 44 ocular OCT B-scans, where 19 scans in each category shows healthy pathology and 25 scans contains pathological symptoms of glaucoma. Furthermore, the proposed dataset contains detailed CDR, calculated by four expert ophthalmologists for both healthy and glaucomic patients. These CDR helps researchers in analyzing the performance of the automated CDSS. Figure 7 shows extracted cup to disc annotations from fundus scan.

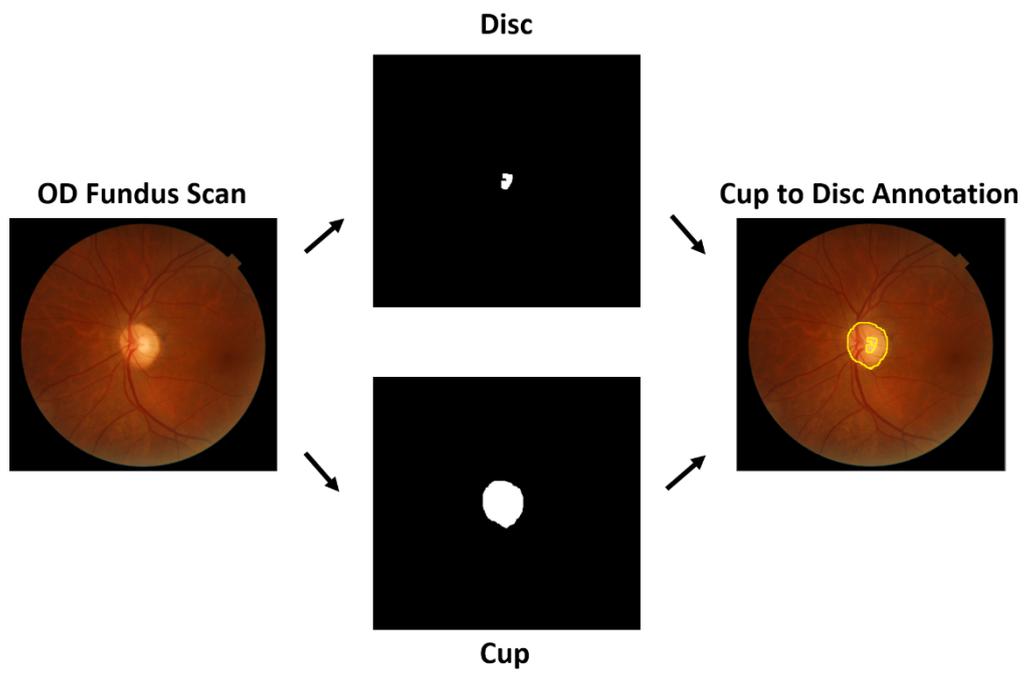


Figure 7: Cup to Disc Annotations from Fundus Photograph

Figure 8 shows the extracted cup to disc annotation from OCT B-scan.

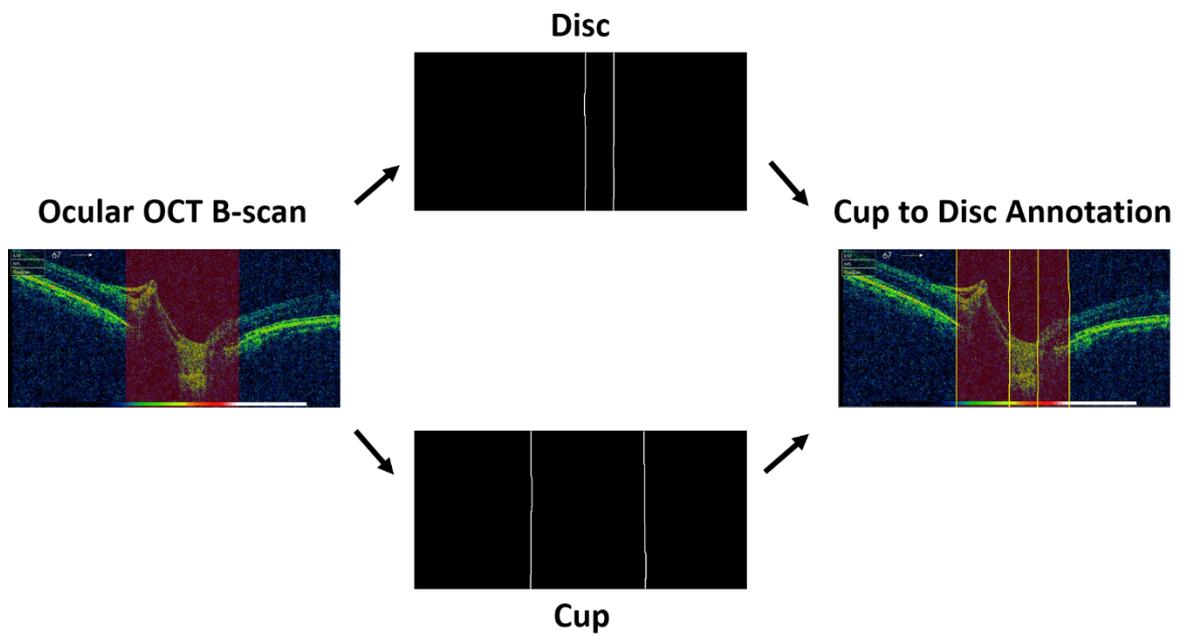


Figure 8: Cup to Disc Annotations from OCT B-scan

Results: OCT images are collected and annotations are also made. However this is a continuous process so we are still working on this and throughout this project and even after that this dataset will keep on updating.

Milestone 3: Requirement gathering for improvement in existing medical record system

Our existing MRS named ALBASR was deployed at AFIO and it was complete desktop application. Health standards like HL-7 was also not being used during development of that system. However based on reviews and international market trends, we are shifting towards web based application with cloud facilities. So that I can be accessed from anywhere and doctors can have access to their patient anytime anywhere. Secondly this version of ALBASR is being developed following all health standards and it will be HL-7 and HIPAA compliance. So this will help us in integration at larger scales and sharing of data not only at national level but at international level as well. User manual which was designed for ALBASR version 1 is also attached as separate file.

Deliverable: SRS for medical record system

Results: A complete SRS has been made based on all requirements. Please see deliverable document.

Milestone 4: Designing web based telemedicine portal

Deliverable: A complete mock up for web based Telemedicine portal

Results: Mockups for telemedicine has been made and updated as well. Please see deliverable document for detailed mock ups.