Team 7
Real-time Tele-Medicine in Ophthalmology

Project Plan: Requirements Specification

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Introduction

Slit Lamp Microscopes are an ophthalmology instrument used to allow doctors to inspect a patient's eyes in detail. The device really consists of two seperate parts. The first is the Slit Lamp which casts a narrow beam of light into the patient's eye to illuminate the ocular structures. The second is a stereoscopic microscope that actually enables the doctor to have a closer view while retaining a sense of depth. The problem with this device is that in order for another person to see what the primary doctor is seeing then they have to view it themselves through the lenses.

It is our team's goal to attach two 4K cameras to the lenses. The video output of these cameras should be sent to a viewing device such as a VR headset for the primary doctor to see. The two feeds should be spit on the left and right side of the screen to retain the depth perception. More importantly, the videos should also be streamed across the internet so that a remote client can view them. This will allow for a secondary doctor to give their opinion or for students to be able to view the operation themselves.

This device would prove to be very useful as it would remove the need for secondary viewers to be physically present. However, this project does not come without constraints. For one, the primary, hardwired viewing device needs to have almost no latency at all so that the doctor can operate in real time. Any lag on this would severely inhibit the doctors abilities. In addition to that, the streamed video needs to have as little latency as possible so that the remote viewer can have efficient conversation with the primary doctor. The data itself that's streamed must also be encrypted and secure in order to comply with the Health Insurance Portability and Accountability Act (HIPAA).

The purpose of this Requirements Specifications document is to establish our project goals. This document will serve as an overarching plan for the project for both our team and for our stakeholders. Within this document will be a breakdown of the project, details of the constraints, use case scenarios, and required deliverables.

Project Overview

The purpose of this section is to elaborate on topics that have already been introduced in the document and provide background information on the factors affecting the scope of the project and its requirements. This section explains who this project is being developed for and how it will be used to aid in various aspects of ophthalmology. It discusses the main features we will be developing as well as constraints we must handle.

The customers and stakeholders for this project are Dr. Eric Higgins from the UK Department of Ophthalmology and Visual Sciences as well as Paras Vora from the UK College of Medicine. Once the project is completed, it will be used and tested by UK Ophthalmology Professors at a high volume ophthalmology clinic in Haiti as they aid in patient diagnosis.

The end goal of this project is to create a live-stream of dual-video cameras attached to a binocular microscope (such as the slit lamp, indirect ophthalmoscope, surgical microscope, and funduscope) that is viewable locally and remotely on multiple devices including a VR headset, smartphone, and 3D display. A large portion of ophthalmology requires the use of these binocular microscopes because depth perception is vital to make diagnoses and perform surgeries. The addition of a low-cost 3D video camera would greatly improve education in ophthalmic disease, allow for novel high-resolution visualizations of ocular pathologies, and provide access to tele-ophthalmology in underserved regions. Currently to view a patient's eyes, anyone who is not the primary doctor would also need to look through the binocular microscope. The technology we will develop to solve this problem does not currently exist in a way that meets the specifications needed by the customers.

The main features of this project will be the local stream of the dual-video cameras to either a VR headset, smartphone, or 3D display as well as the remote stream. To do this, we will need to interface with hardware, implement a server, and develop a user interface. After we complete the main features we plan to implement smaller features such as snapshotting, recording, and camera setting controls (exposure, contrast, and shadows) to improve the usefulness of the application.

A significant factor that will affect the performance of our project is that the video is to be streamed using 4k resolution. This requires more data to be sent as opposed to 1080p (the standard for "high-definition"). Another factor that will affect the quality of our project is the crossover between processing power and portability. Our customers have indicated that they would like the entire system that we create to be quite small; they suggested that we research embedded computing systems such as the Raspberry Pi. While the newer iterations of the Raspberry Pi have multiple processing elements, built-in wireless connectivity, and a respectable amount of memory, they are still underpowered relative to modern desktop computers. Implementing a high-performance 4k streaming system using limited computing power will be challenging, but not impossible.

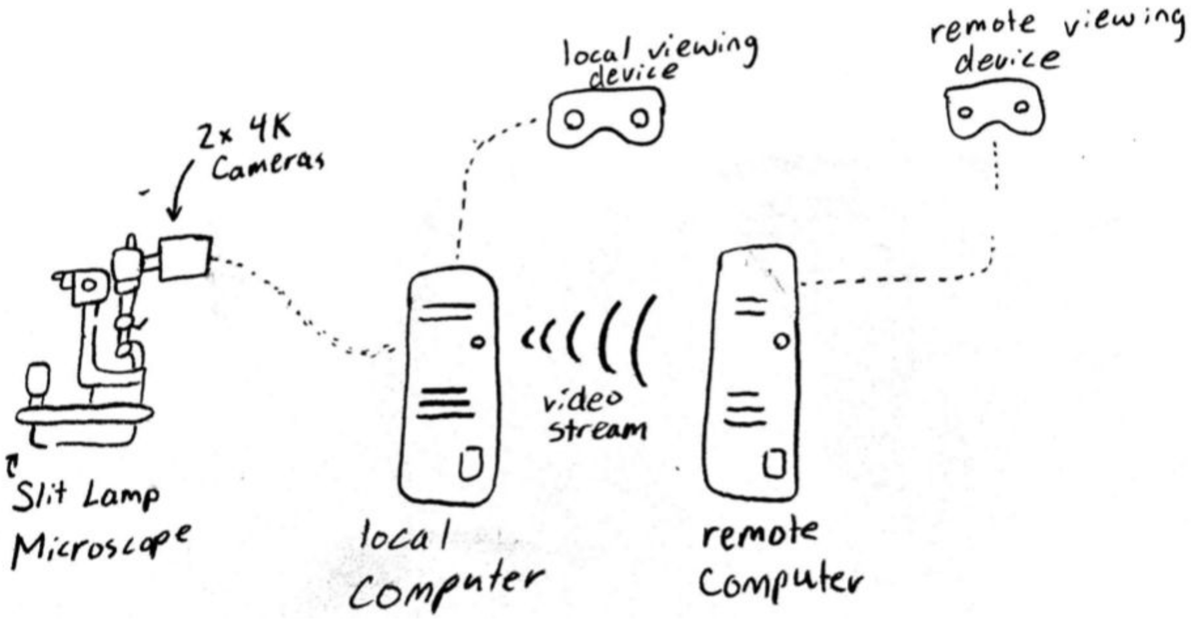
Development and Target Environments

This section describes the required hardware and software platforms/packages in order to implement a functioning system. To start, fundamental to our system is a slit lamp which is a key technology used in eye exams, and then two 4K cameras, one for each eye. So rather than an opthamologist looking through the slit lamp we are aiming to digitize the process by using 4K cameras rather than physically looking through the slit lamp.

We will be using Python for our project, and more specifically the OpenCV and Flask libraries. OpenCV will be used to take the 4K cameras and actually display the feed they are capturing. It will be important to make sure this is done in a way that maintains the highest level of quality possible. From there, we will use Flask in order to develop the web framework to allow for viewing of the data from the cameras in off-site locations. The data will need to be displayed and sent in a way that is as efficient as possible in order to maintain the highest quality with the least latency possible for this process.

System Model

Our project is a complex one. There exist many different components to our system, each interacting and communicating with others components. The goal of this section is to clearly define each functional part of our system and their roles and interactions with the rest of the model. Please refer to the model diagram to see a depiction of the model.



There exist six major components:

1. **Slit Lamp Microscope**: this is the main instrument that our team is trying to retrofit new, modern technology onto. The Slit Lamp Microscope will be where the eyeball that we're trying to look into will be. Attached to the two stereoscopic lenses will be two 4K cameras.
2. **4K Cameras**: There will be two 4K cameras--one of each screwed into the lenses of the slit lamp microscope in order to capture the stereoscopic views of the patients eyeballs. The feeds of these cameras will be transmitted over HDMI cables connected to the local computer.
3. **Local Computer**: receives and processes the two 4K video feeds from the cameras using Python and OpenCV. It will then take this data, manipulate it as needed (grayscaling, stereoscopic framing, resolution shift, etc.), and send it to two places. One destination of the feed will be a local viewing device at real time speed sent over HDMI. The other destination will be a remote computer, sent over a Flask server.
4. **Local Viewing Device**: Some type of 4K stereoscopic display such as Google Cardboard that receives the operation stream from the local computer over HDMI.
5. **Remote Computer**: A non-local computer that receives the video stream(s) over a TCP connection to the local computer. The remote computer will send the video frames to a remote viewing device over HDMI.
6. **Remote Viewing Device**: Some type of 4K stereoscopic display such as Google Cardboard that receives the operation stream from the remote computer over HDMI.

User Interaction

First of all, the primary users of our projects are going to be opthamologists and their coworkers. The primary user interaction will be for opthamologists to analyze the view of the slit lamp through a VR or on regular screen through the cameras rather than physically using the lamp. So a patient will be situated in the slit lamp with the cameras and the opthamologist will be able to make diagnoses based upon what they see on a 4K screen. Additionally, they will be able to take pictures and/or record what they see to maintain necessary records and documentation. The next stage of user interaction is going to be for opthamologists that are off-site from where the patient is. Another opthamologist may log into the web server online and be able to consult with other ophthalmologists or patients real time without being in the same room. This could also be used in a surgical setting to allow for outside additional consultation when performing intricate surgeries or when facing problems where outside consultation is needed.

Functional Requirements

This section of the document describes the functional requirements for our project. The requirements listed below explain what the solutions we create will do. Since the first goal of our project is to get the 4k video stream displayed locally, requirements one through four will be the first that we focus on. We will complete the rest of the requirements after these. After listing the functional requirements below, there will be more detail on certain requirements and why they are being imposed.

Our functional requirements are as follows:

1. The two 4k cameras need to be mounted on the slit lamp and connected to a computer.
2. Th computer connected to the 4k cameras also needs to be connected to either a portable display or a VR viewer.
3. The computer will receive the video stream from the cameras and display it on the connected device.
4. The latency from the computer to the connected device needs to be minimized as much as possible.
5. The local machine needs to host a server and provide the video feed to remote viewers.
6. The latency of the data transfer from the server to the remote device needs to be minimized as much as possible.
7. The video feed that is being sent via the server needs to be encrypted and secure in order to comply with the Health Insurance Portability and Accountability Act (HIPAA).
8. We need to develop a user interface which displays the video feed and other camera settings and controls such as exposure, contrast, and shadows.
9. The user interface should have options to screenshot or record the video stream whether it be local or remote.

The purpose of requirements one through four are to allow a secondary doctor to view a patient's eyes, without having to look through the slit lamp that the primary doctor is viewing. This will allow more than one doctor/person to examine what is happening. The latency needs to be minimized so that both viewers see the same thing at relatively the same time. If there is any type of lag this could inhibit the secondary viewers abilities.

The need for the video feed from the server to a remote location is to allow a doctor to assist during surgery or an ophthalmological procedure as well as for teaching purposes. While the latency being minimized here is not as critical as the local stream, it still is an important factor.

HIPAA is the United States legislation which ensures privacy and security for citizen's medical information. Since ophthalmology is a medical field we must abide by this.

The user interface needs to be simple and easy to use. The extra camera settings and controls we want to implement should be basic so that a non-technical person can use them with ease.

Nonfunctional Requirements

While the general idea sounds straightforward, writing the software behind it will be a challenge. In fact, there are a variety of programmatically based challenges with this. The main challenges with this project end up boiling down to the fact that 4K video alone is a *lot* of data to move around and to process. Each frame of the 4K video stream is around 24MB. Even harder than that is moving around *two* 4K video streams. There will be difficulties in both putting the stream on the hardwired viewing device as well as streaming it over the internet.

A complete breakdown of the non-functional requirements in order of most important to least:

1. The system must operate with minimal latency (real-time) to be applicable for all our customer's desired applications.
2. Must use the open source Python computer vision library OpenCV to process the camera feeds.
3. Must host a server using Python's Flask module to stream the data.
4. Resolution of both local and remote side need to be 4K.
5. Display images must be converted to proper VR/stereoscopic view frames.
6. The stream needs to be sent over encrypted HTTPS in order to comply with the Health Insurance Portability and Accountability Act (HIPAA)..
7. The client side needs to be verified over some sort of private user validation.
8. The remote side viewing should have simple UI elements to allow the user to control the stream's resolution and colormode (RBG/grayscale).

Feasibility

The purpose of this paragraph is to explain the different versions of our project we plan to complete. We will start with the absolutely necessary components that we plan to get done, and then extend our work to important, but less critical features.

The first version of our project which is our main priority to get done is a live-stream of dual-video cameras attached to a binocular microscope (such as the slit lamp, indirect ophthalmoscope, surgical microscope, and funduscope) that is viewable locally on multiple devices including a VR headset, smartphone, and 3D display. This also must have a basic user interface to display the video feed.

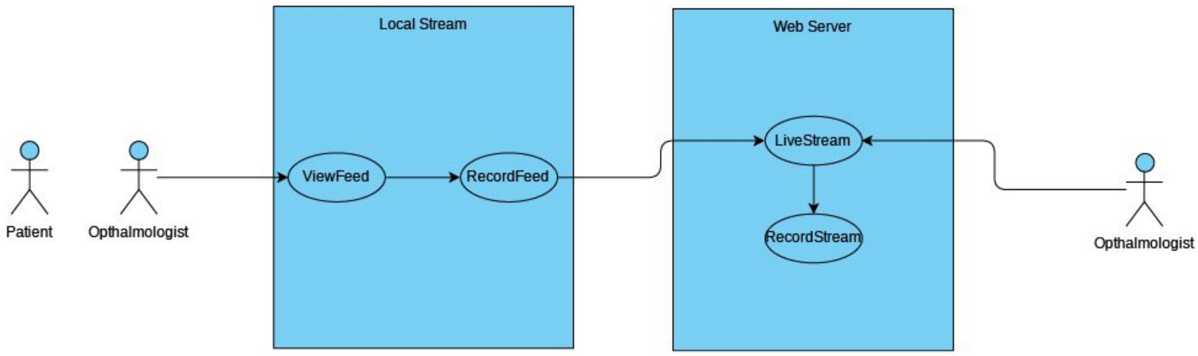
The second version of our project which we also hope to complete by the end of the semester will extend this live stream to be able to be viewed remotely. This will also need a user interface to display the video feed. After this version is completed we will work on implementing features such as snapshotting, and camera setting controls (exposure, contrast, and shadows) to improve the usefulness of the application.

Conclusion

Overall, this project will be a challenge for our team. We will soon face many challenges involving large data communication, computer vision manipulation, secure server streams, and many more unforeseen challenges. However, once the challenges are overcome and the project complete, the result will prove to be very beneficial to both health professionals and students alike. This document shall act as a guide for both our team and the stakeholders throughout the lifecycle of the project.

Appendix

Link to Developer Notes Site: https://github.com/coleterrell97/SeniorDesign
Use Case Diagram:



System Model: