Adaptive Optics Retinal Imaging with Eye Tracking

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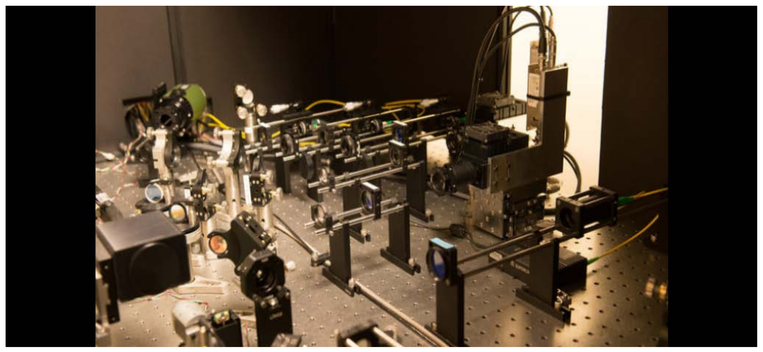
ABSTRACT

The adaptive optics scanning light ophthalmoscope (AOSLO) is a custom-built retinal imaging system being used to support the research at the Clinical and Translational Imaging Unit of the National Eye Institute (NEI). It contains a series of light sources and mirrors that ophthalmologists utilize to image the human retina. However, the human eye is in constant motion, even when one is attempting to gaze at a fixed point, making it more difficult for the AOSLO to capture sharp images and observe a fixed location over time. This eye motion can be compounded when patients have ocular diseases or poor vision. Correction for eye motion is essential for improving the robustness of imaging and subsequent data analysis.



Sample AOSLO Machine from University of Pennsylvania

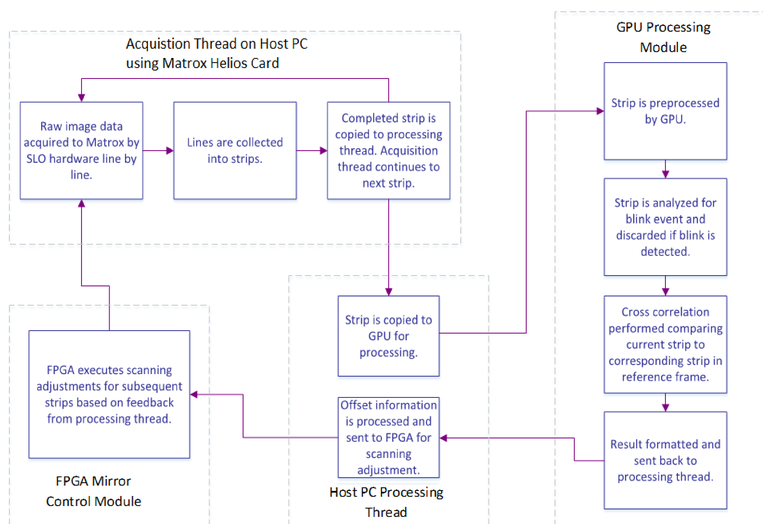
DUPLICATION OF SYSTEM

The AOSLO is regularly used for clinical research and that activity cannot be interrupted for development purposes. Therefore, duplication of the existing host PC is necessary to have an available platform for development. An identical PC was attained and outfitted with the required components prior to this project, however it needed to be configured with all the software required to run the system. The cloning process was complicated by a series of DLL and compilation issues. When transferring project files to the testing machine, there was "DLL Load Failed: The operating system cannot run %1" error that crashed the software. This issue was primarily due to the faulty SSD used to create a cloned copy of the host PC. In addition, differences in Matrox software between versions 9 and 10 led to further compatibility issues. This problem was ultimately solved by obtaining a copy of Matrox Imaging Library 9. Once all the components were in place on the duplicate host PC, the system variables were reconfigured so that all the necessary components were within the scope of the operating system at runtime. However, new ongoing complications arose stemming from compatibility issues between CUDA and Visual Studios. The newest version of CUDA 9.2 is not compatible with VS 2017, requiring the code to be run on VS 2013, while non-CUDA specific code was optimized using v140 build tools found on VS 2015 and later.

OBJECTIVES

The purpose of this project is to design and integrate a closed-loop optical stabilization module into an existing AOSLO system. The module will adaptively adjust the position of the retina scanning module to correct for natural ocular motion to produce better images and provide a stable image over time of a localized view of a retina. This will be achieved by combining two methods which extend on developments at the University of Rochester : within-frame motion correction at the strip-level and final correction at the frame-level. With this technology, researchers will be able to obtain a better picture of retinal diseases and the human eye in general.

Eye Motion Correction
During Frame Acquisition



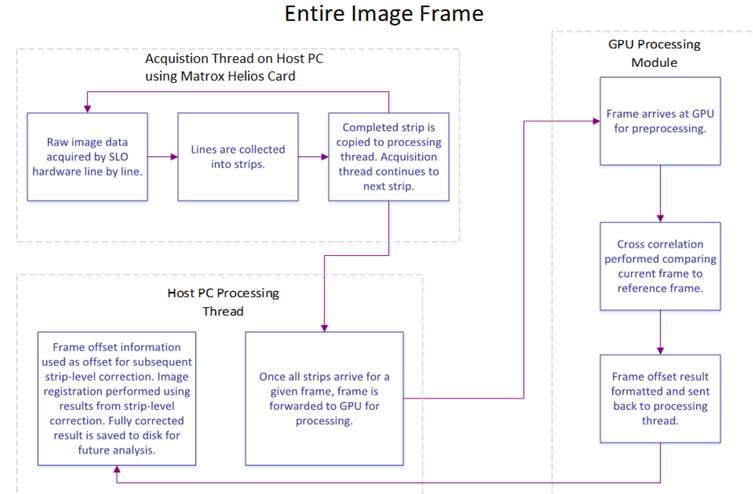
HOST PC COMPONENTS

- Matrox Helios video acquisition card and the associated Matrox Imaging Library (MIL)
- NVIDIA graphic processing unit (GPU)
- Field-programmable gate array (FPGA)
- Languages: Python, C++, CUDA, MATLAB, and LabVIEW
- Simplified Wrapper and Interface Generator (SWIG)
- Chocolatey Package Manager

METHODS

Planned algorithm development for eye movement correction involves two main approaches: within-frame motion correction at the strip-level and final correction at the frame-level. Images of the retina are acquired in strips, where each strip consists of a defined number of rows within a single image frame. After receiving a strip, the data will be copied to a processing thread and a GPU will use cross-correlation to compare the current strip to the corresponding strip in a previously selected reference frame. This comparison will yield a spatial offset between the strips which will be used to adjust the scanning mirror pattern via the FPGA to account for eye motion. Eventually, after all strips are acquired, the system will calculate eye motion for the entire frame relative to the reference frame to generate an offset that will be used for subsequent motion calculations at the strip level. Additionally, a second round of cross-correlation between multiple strips in the current frame and reference frame will be performed to filter out any spurious motion and image artifacts if they are found to be significant.

Eye Motion Correction for
Entire Image Frame



CONCLUSION

The work completed this summer helped pave the way for implementation of optical stabilization on the AOSLO system through real-time retinal tracking and image registration. Development will continue beyond this summer and, when finished, the closed-loop optical stabilization module for the AOSLO system will be able to aid researchers to investigate and understand more about the human retina. Without the distortions and data loss associated with constant eye movement, scientists will be able to more accurately and effectively study the human eye. This research has many future implications such as minimally invasive retinal procedures, as ophthalmologists will have a clear field of vision without having to perform conventional surgery.