Final PROJECT PROPOSAL MAE6291: IoT for Engineers

Spring 2025, Instructor: Prof. Kartik Bulusu (MAE Department, GWU)

Midterm PROJECT TITLE	Live Image Intensity Tracker	Category: Circle One	Grad Undergrad
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I. INTRODUCTION Central problem being addressed; Topic of study related to problem [1.0 Points]

When taking a photo with a camera, proper lighting is a must in order for the photo to survive deletion. How much light is too much light will depend on various factors, but the key is to make use of the entire range of light that the camera is able to capture, which is dependent on the number of bits the camera has. There is no use to flood the scene with light, that will result in an entirely white image and will surely get deleted. This is where light intensity comes in. An image is made of a series of pixels, each assigned a light intensity value from 0 to 2 raised to the power of the number of bits (minus 1). The scenario where there is a completely white image is a result of saturation. All the pixel values of the image read the max intensity value, which means that there is information being lost from the scene being captured due to the amount of excess light. For everyday photography, turning off the flash and retaking the photo will do. But in the research landscape, this is an issue that can hurt the quality of one's data. This project attempts to address this issue in experimental settings.

II. BACKGROUND AND SIGNIFICANCE Problem details; Rationale; Problems addressed; Research methods and sources. [1.0 Points]

This project is inspired by a specific issue from the lab I work in. One imaging technique the lab deploys is plenoptic imaging, which uses of a microlens array (MLA) to get multiple perspective (elemental) views of the object, which allows access to angular information at the expense of spatial information. The system currently in use has 7 elemental views with one in the center and a hexagonal array of views surrounding it. Camera alignment is crucial for getting the best quality data, however, with measurements on the order of microns, this is not a straightforward task. One indicator of an aligned system is the intensity profile between the elemental views. The view directly left of the center view should have a similar intensity profile as the view directly right of center. If that is not the case, minimal camera adjustments must be made to correct that error.

What makes this project ideal for this application is how it saves time and storage space. The current process for determining if the system is misaligned is by recording our data, exporting it from the software, and using an application like ImageJ to look at the intensity profiles. The project being proposed will cut that process down to running a code and searching for the webpage that displays all the relevant intensity data at that moment, which will help inform system adjustments on the fly. The plot will also reflect whether or not there is any saturation. This is also important for this application, as it is extremely difficult to detect if the images are saturated with the naked eye. This will show up after we export and analyze the data, making us frustrated that we have to redo the experiment.

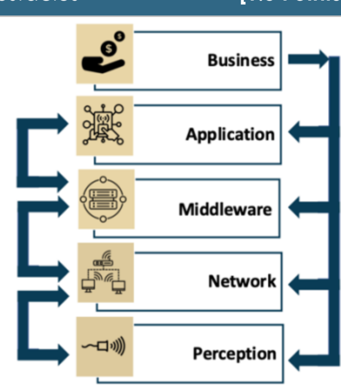
III. LITERATURE REVIEW Cite, Compare, Contrast, Critique, Connect [2.0 Points]

I have worked closely with Steven Williams on his thesis about measuring the wall shear stress using Fourier Integral Microscopy [1]. This technique involves placing the MLA at the Fourier plane to achieve orthogonal elemental views that retain telecentricity. The area that gave Steve some trouble was when performing the Point Spread Function (PSF). In short, the result of the PSF will be used in a deconvolution scheme that removes the blurring that appears in the data. This involves shining a light through an incredibly small pinhole to create a point source and translating the camera axially towards it in order to characterize the axial and angular resolution. Where this becomes a problem in Williams' system is when there is misalignment with the camera relative to the pinhole, as even the slightest of errors will propagate with the translation of the camera. This causes, as Williams puts it, a "discrepancy in peak values" among the elemental views. He puts this down to small misalignments, which can be used to explain any deviation between theoretical and measured values.

IV. PROJECT DESIGN AND METHODS Figure out what you need for the project; Think about potential obstacles [1.5 Points]

Hardware Components:
- RaspberryPi 4
- PiNOIR Camera: to obtain the live images

IoT Architecture:
- Business: Market for researchers that could do with on-the-fly data of their images
- Application: Webpage (Flask) with live plot of intensity values (plotly)
- Middleware: RaspberryPi with Python (OpenCV library to read image as intensity values)
- Network: a localhost web server will be created using Flask and will be tunneled to the internet using cloudflare
- Perception: Camera picking up live images, a 1D slice of the intensity values of the image (either user defined or preset) are used as the data to be processed and plotted



Potential Challenges:
- Latency of the camera

Edge Computing:
- Data visualization of the intensity profile
- Signal processing for a cleaner signal (ie Gaussian fit)
- If the criteria is met (gaussian curve, no saturation), various statistics can be calculated. For example, in the case of Williams, calculating the Full Width Half Max (FWHM) of the PSF yields the lateral resolution [2].

V. PRELIMINARY SUPPOSITIONS AND IMPLICATIONS Task division; identify who is doing what if you are in a team of two [2.0 Points]

As an individual project, my tasks include:
- Ensuring the camera is fully functional and integrated into the code
- Figuring out the best way to handle the data from the camera to avoid a standing ovation.
- Determine the best method for calculating the image intensity
- Presentation of the data: In a plotly graph with live updates

VI. SUMMARY Why is this problem worth addressing; Why this problem is unique and how it advances existing knowledge [1.0 Points]

In order to advance the work of Williams and other researchers utilizing plenoptic imaging, we must strive for increasingly higher levels of accuracy. A contributor to errors in the data comes from the misalignment of a system. With the small scales that Williams is working in, it is impossible to detect misalignments and saturation with the naked eye. The proposed project will serve as a prototype in tracking the intensity of the image in real time to allow for quick adjustments to the system without having to go through the laborious process of recording, extracting and analyzing the data before finding out that adjustments need to be made.

VII. REFERENCES References; Bibliography [1.5 Points]

[1] S. Williams, "A Novel Compact Fourier Integral Microscope Design for Wall Shear Stress Measurements." Order No. 31556315, The George Washington University, United States -- District of Columbia, 2024.

[2] S. W. Hell, S. Lindek, C. Cremer, and E. H. K. Stelzer, “Measurement of the 4Pi-confocal point spread function proves 75 nm axial resolution,” Applied Physics Letters, vol. 64, no. 11, pp. 1335–1337, Mar. 1994, doi: 10.1063/1.111926.