DLA Report 5

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1 Description of what was done

1.1 Summary

The big result of this report is that I was able to take non-blurry pictures of waves indoors and produce a non-slanted 3d surface height reconstruction. This was achieved in part by creating slower waves with larger wavelengths by decreasing the depth of the water in the glass tray - something I had not considered before. I also used the LED panel, which I had to wire together to work. I also found image registration code to align my images more robustly than I was doing previously. Lastly, I spent some time with Mark to develop my DLA summary which is due Dec. 1^{st}.

1.2 DLA Summary

I met with Mark on October 25^{th} to get help with writing my DLA Summary. The summary is mandatory as part of being in DLA. We talked about the project's goals, how it fits into other research, and what needs it will eventually fulfill in the field of nonlinear waves. Mark has already returned an edited version of my summary which I have yet to go over. The summary is due December 1^{st} with Mark's signiature.

1.3 Experimental Setup

For this report my goal was to use the LED panel to take higher quality images in the hopes that it would improve the results in reconstructing the water surface. I first unboxed the LED Panel and noticed that it was bent.

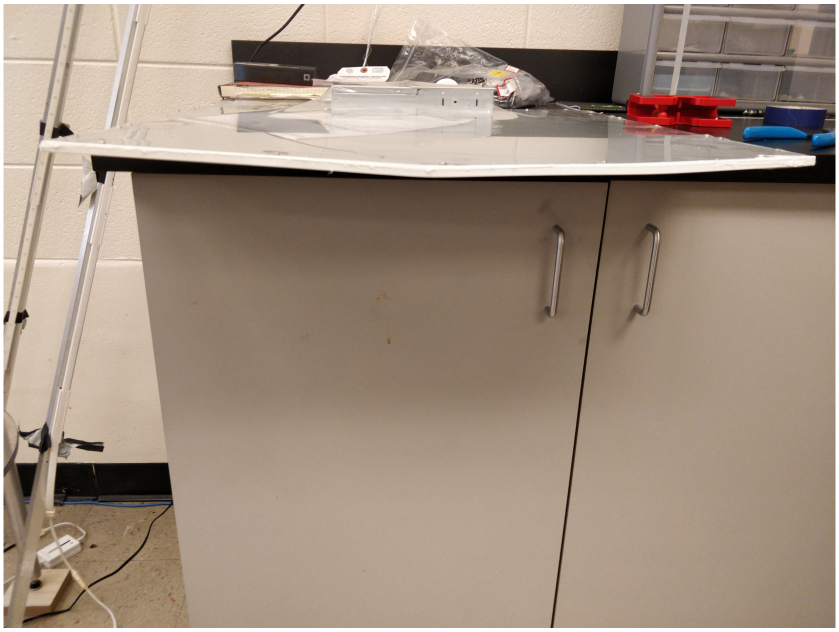
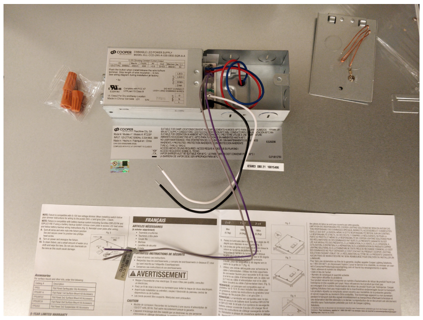
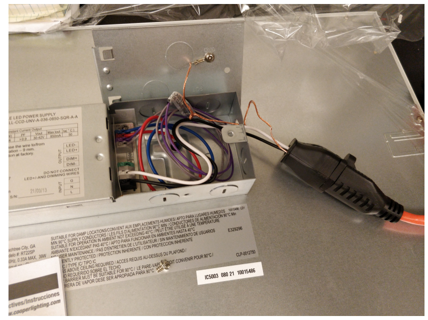


Figure 1: Bent Panel

This was easily solved just by bending the panel back in the other direction, though I was a bit concerned about whether or not the internals were damaged (it appears they were not). I then looked at how to power on the panel. It turns out that since the panel is for industrial uses, wiring is necessary. So, I went to McGuckin's Hardware Store to buy a wire-to-outlet adapter and an extension cord. I then wired everything together. Afterwards, I covered the wires in Gaffer tape because exposed 120V electricity is scary. Please note that the LED is dimmable, but I didn't include a dimmer because I'm assuming we want the LED to output at max brightness all the time.



(a) Before Wiring



(b) After Wiring

(c) After Gaffer Tape

Figure 2: Stages of the LED Panel's wiring

After setting up the panel, I went ahead and set up a camera on a tripod above the LED panel. I leveled the panel by placing skewers underneath. On top of the panel I put the dot pattern and then a glass tray filled with water. I also placed sticky notes so that I could later align the different images I would be taking.

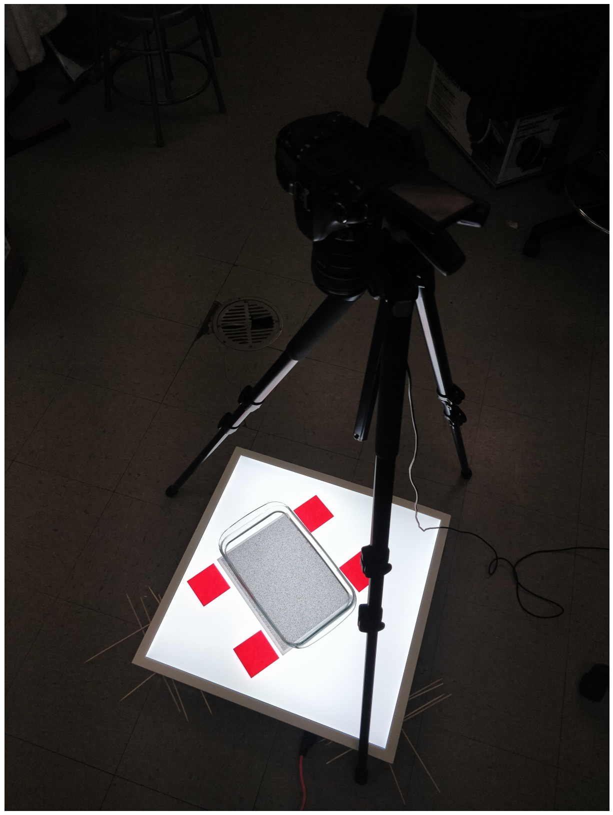


Figure 3: Experimental Setup

1.4 Image Registration

After taking the images from my experiment, I took Mark's advice from an earlier meeting and looked into image registration. MATLAB has a lot of resources around built-in image registration algorithms. In fact, there is a tutorial for my exact situation: my images are "distorted by some combination of translation, rotation, and scaling". For the following figures, I used one sample image and created another one by translating, rotating, and scaling the original. I then align the second image back to the first by performing a geometric transformation. To get the geometric transformation, one needs to select "control points" between two images. This is done by selecting points that you know should be the same between the two images:

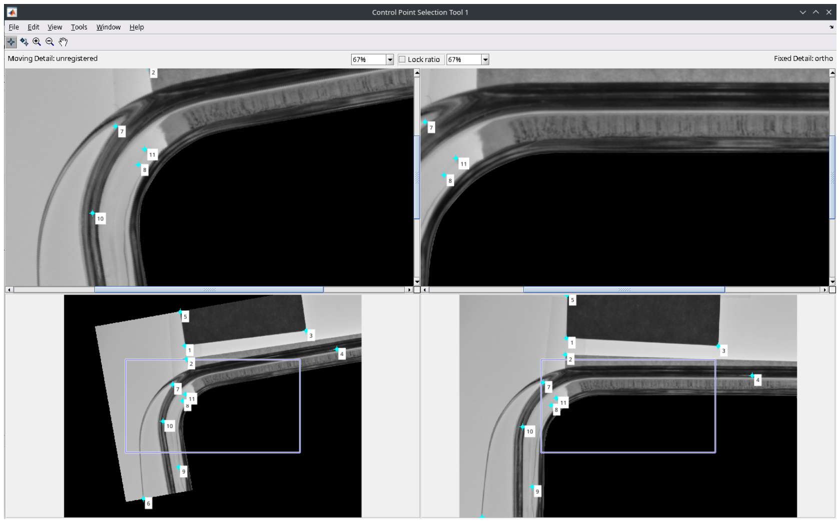
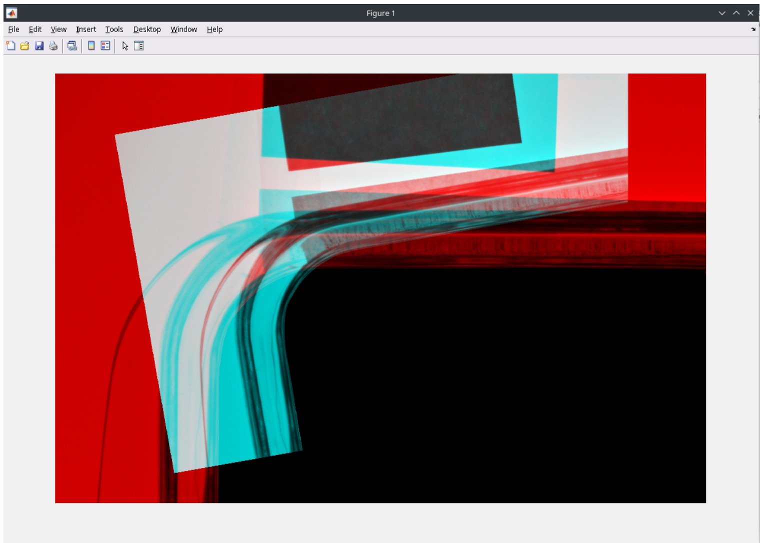
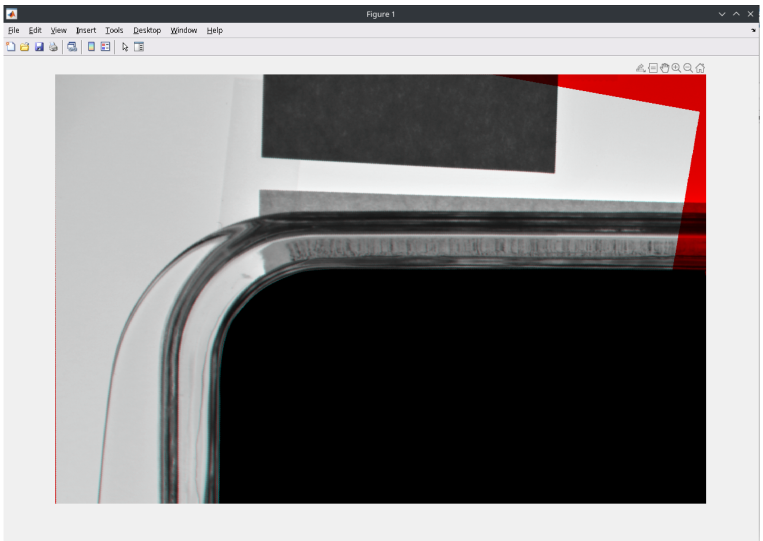


Figure 4: Control Point Selection for Two Images

Below demonstrates the result of MATLAB re-aligning the two images:



(a) Before alignment



(b) After alignment

Figure 5: Re-aligning two images

This is a much more rigorous way of aligning the two images than my eyeball method I was using before. It's also much faster, so I'm pleased with these results. Note that automatic control point selection is possible in MATLAB but it required my computer to have more than 16GB of RAM due to the high resolution of the images I took and the matrices it was creating while processing the algorithms. As a result, I didn't pursue automatic feature selection here, though I do have working code from a tutorial.

1.5 Image Blur

One of the primary reasons I believed taking images with the LED panel would improve image quality is a decrease in ISO. As mentioned in my previous report, the waves from taking pictures indoors were blurry, and I believed that to be a result of ISO above 3,000. By using the LED panel, I was able to take pictures with ISO 250; despite this, the images still appear blurry where the largest waves are located.

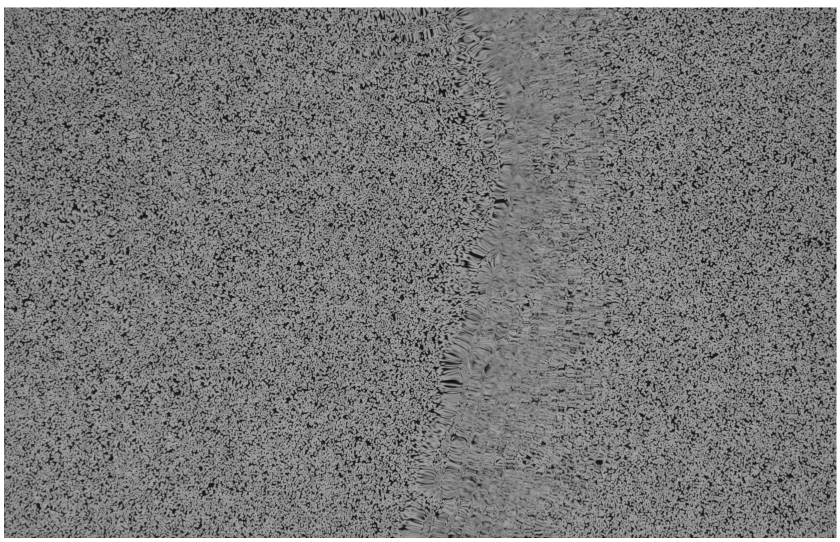


Figure 6: Blurry Waves with ISO 250 (Indoors)

Compare this to the waves taken outdoors.

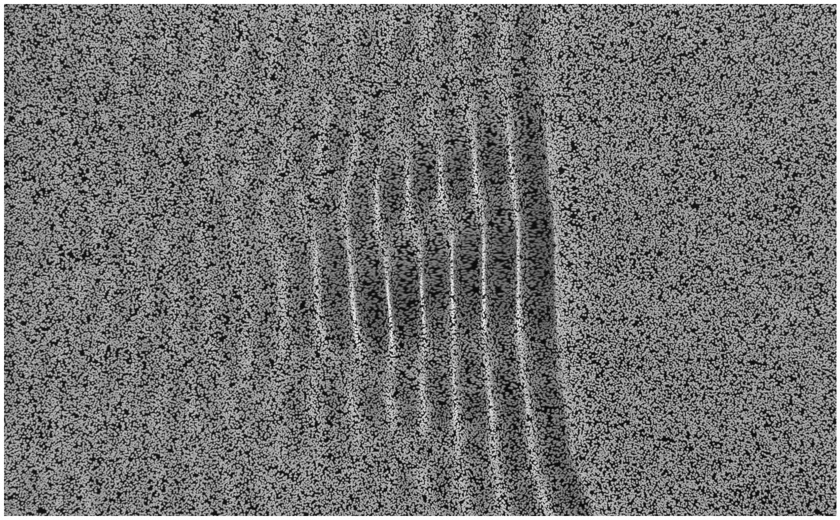


Figure 7: Not Blurry Waves with ISO 100 (Outdoors)

I was unable to lower the ISO to 100 in this experiment since the resulting images looked too dark. I kept the aperture and shutter speed the same between the previous two figures. Later in the report I experiment with the camera settings and experimental technique to resolve the issue with blurry images.

Next I use the images from this set of pictures to reconstruct the surface.

1.6 Surface Reconstruction 1

After going through the two trials of pictures I took and aligning all of the images together, I re-ran the OpenPIV and pivmat code to reconstruct the surface heights. Here I'll show a pair of images I found the most promising, based on what I thought had a good balance of minimizing blur and increasing water movement. Since I used image registration I could rely on the two pictures being aligned.

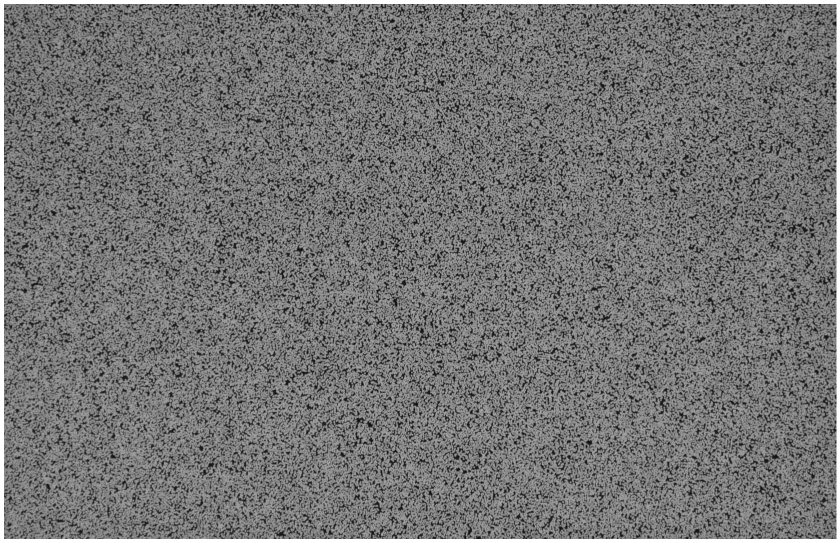


Figure 8: Still Water

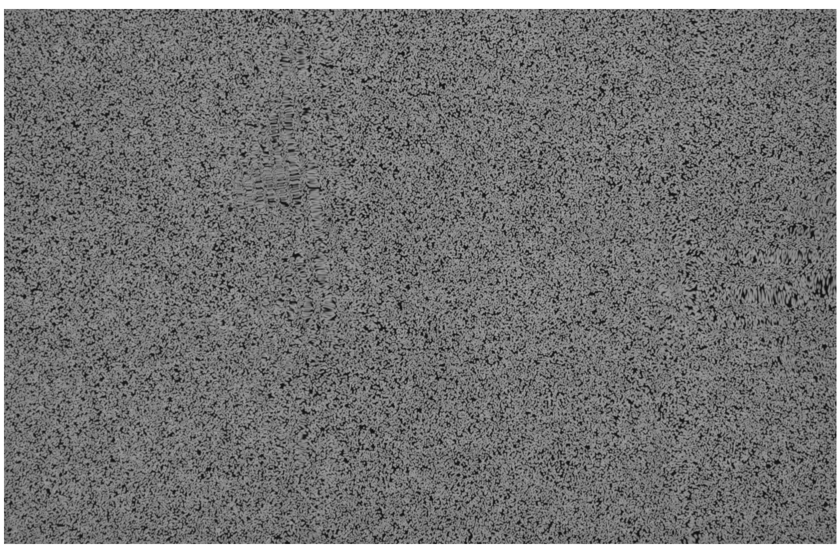


Figure 9: Moving Water

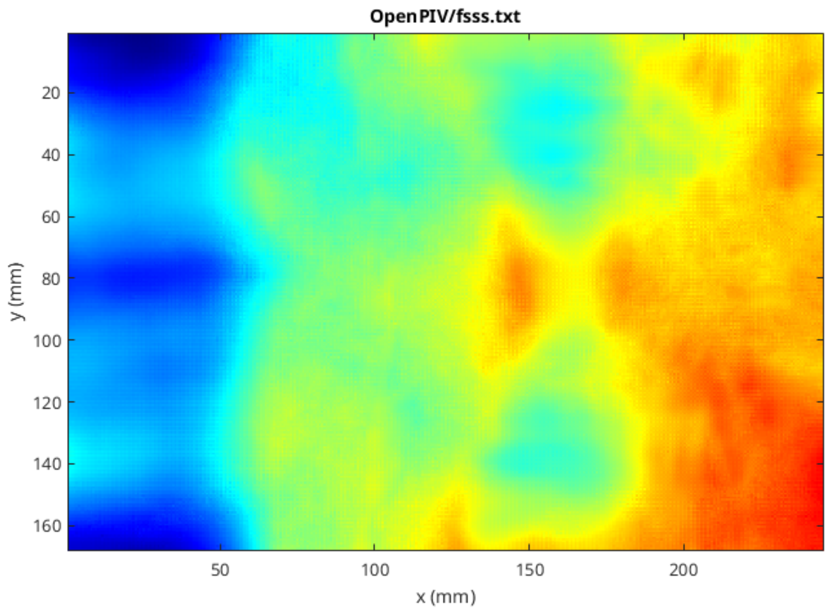


Figure 10: Surface Reconstruction 2D

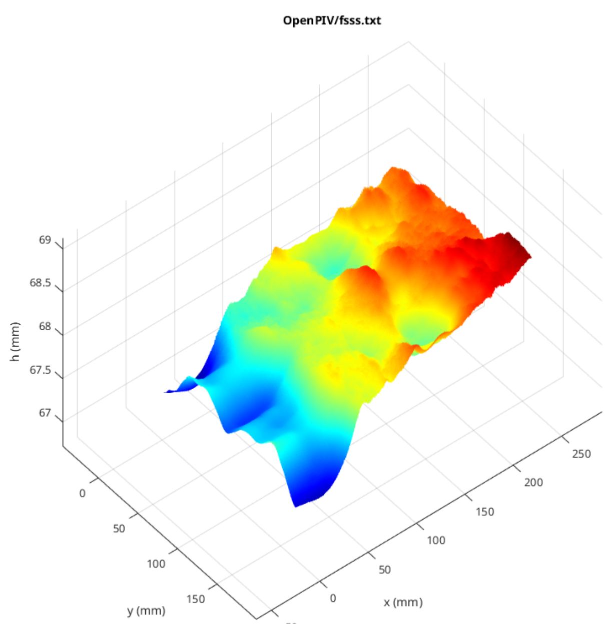


Figure 11: Surface Reconstruction 3D

As you can tell, this doesn't look nearly as good as the original pictures I took outdoors. In my displeasure, I decided to look back and see what features my outdoor pictures had that are not present here. What ended up helping was overlapping the images in cyan-red color channels.

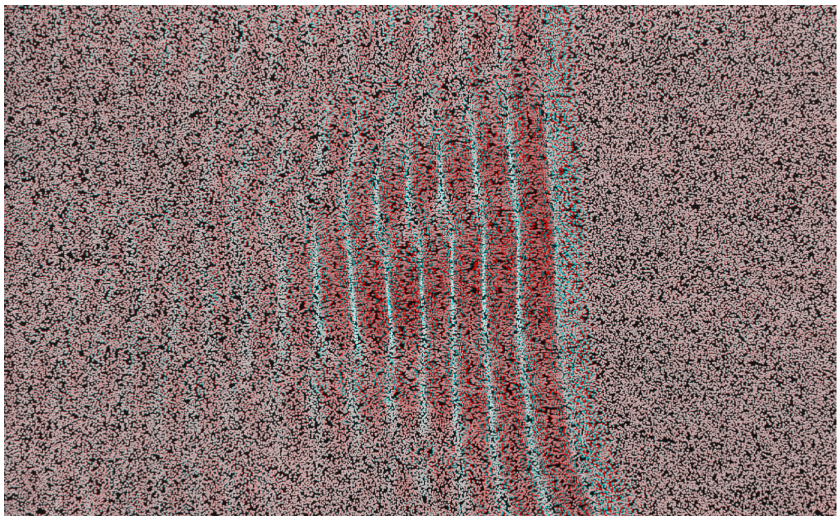


Figure 12: Outdoor Cyan-Red Images

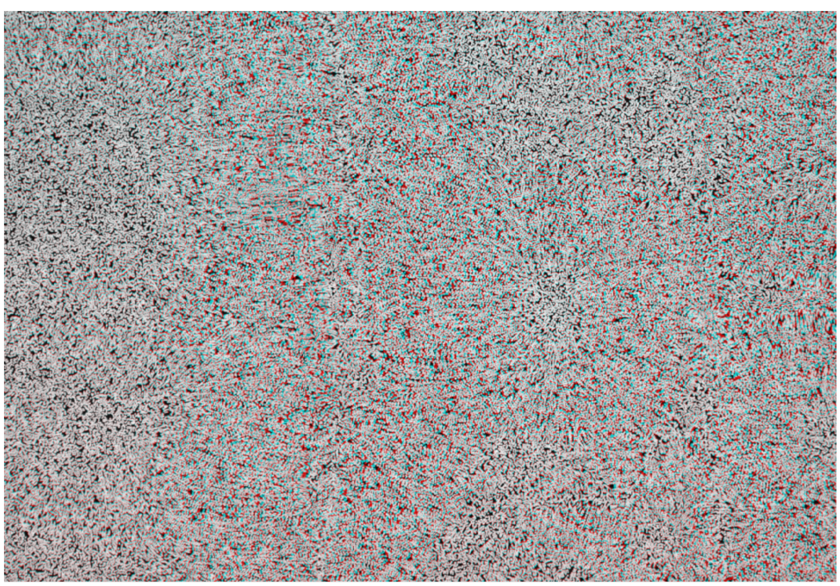


Figure 13: Indoor Cyan-Red Images less-blur

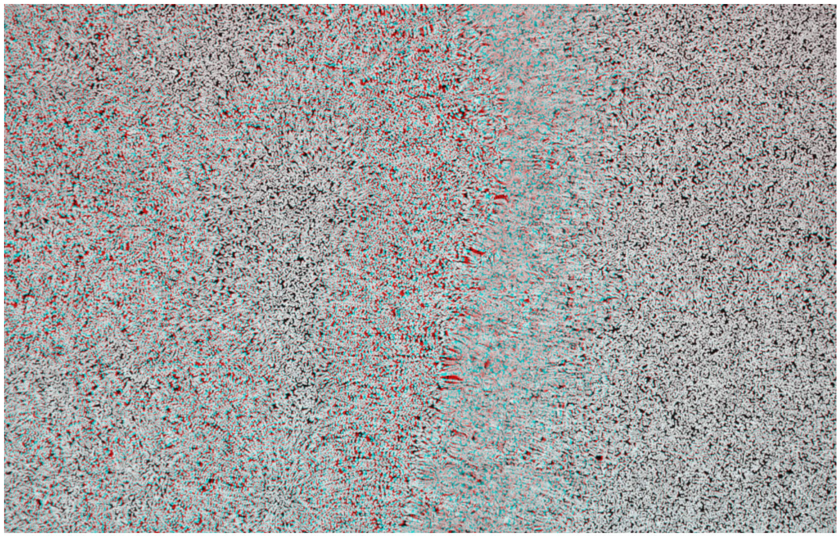


Figure 14: Indoor Cyan-Red Images more-blur

I'm under the impression that the water height is the same where the pattern is clear and white in the Cyan-Red images. This is could be the reason why in 12 the pattern lines up near the high-amplitude waves but not on the outside of the image. This implies that the water level differs in that outer area between the still and moving water images. The other reason for why 12 appears more red is because I didn't have a good alignment method like image registration, so the two images could just be shifted. The observation that the pattern is clear and white where it lines up between the two images also leads to the conclusion that 13 and 14 are not good images. They both have a lot of water movement that wouldn't result in a clear structure in the surface height. A clear structure is necessary to verify the algorithms I'm using. You can see that the water is moving all over the place yourself by analyzing where the pattern is the most clear for 13 and 14. You should find that the pattern is clear in different spots all over the two images. This also leads to the conclusion that the software might not be performing as poorly as I thought. After looking at 13 and comparing it to 10 and 11, it looks like the water height reconstruction might be more accurate than initially though. Again, though, I need images where it's clear what's going on to tune FSSS to be more accurate.

I think that my next step is to change the way I generate the waves, since from the Cyan-Red images it's clear that the water is moving all over the place. This can be remedied by having a machined piece of acrylic where we know the surface height and can compare it to the results of FSSS. This can also be remedied by using the water table, where we create a steady wave. As it currently stands, manually moving the glass tray results in inconsistent wave patterns that sometimes contain waves going in all directions. I believe that I got lucky in creating the wave in my outdoor experiment, since I've been using the same method to generate the waves for both indoors and outdoors experiments. It's also possible there is some post-processing going on with the camera, though some preliminary Google searching didn't seem to support this idea.

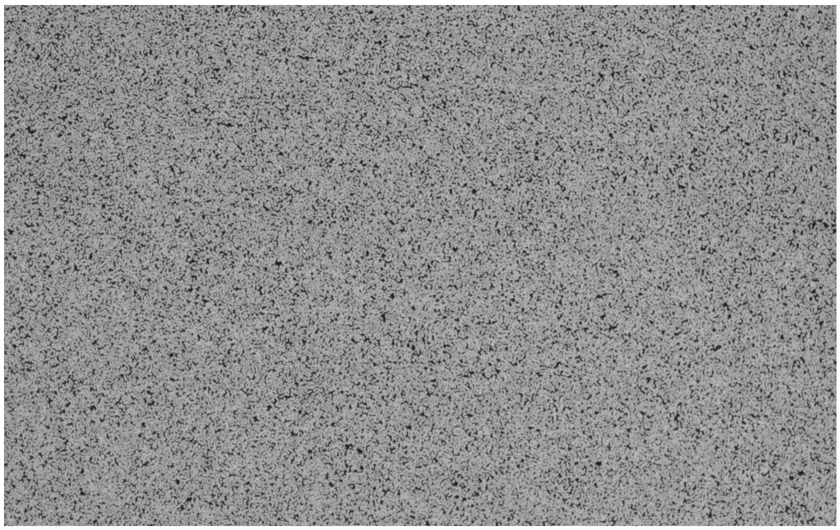
1.7 Surface Reconstruction 2

I went back into the lab to test the hypotheses I made. I messed with the camera settings and the way I generated the waves. Initially, I set up the experiment exactly as I did before in order to be able to change the camera settings. I found that I needed to increase the shutter speed to around 1/2500 in order to significantly reduce the blur experienced before. This also meant that my ISO had to increase to 1250 so that the image wouldn't be dark. This, however, resulted in higher quality images despite some noise/grain from such a high ISO.

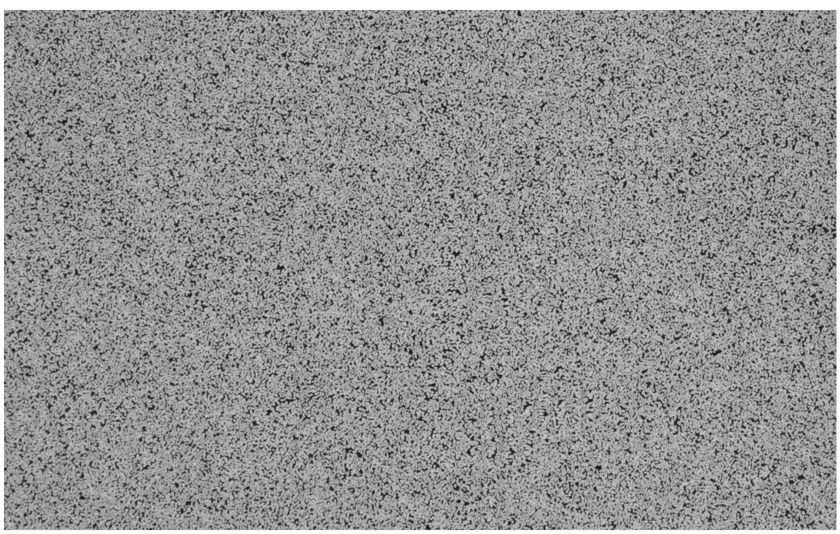
Figure 15: Indoor Image with No Blur

The next observation I made was while I was filling up the glass tray. I noticed that the when the glass tray was more full, the waves generated from lifting the glass tray on one end and then setting it back down moved faster and had smaller wavelengths. Therefore, less water in the tray is likely why the waves from the outdoor image 7 appear to have larger wavelengths than in 15. In fact, the shutter speed of 1/640 for the outdoor image makes sense because the wave was likely traveling much slower than in my indoor experiments. As a result, if I continue using this method I'll need to have less water in the tray in order to image waves without absurdly small and fast waves until the water table or acrylic piece is set up. The water table/acrylic piece will let me use longer shutter speeds and lower ISO since the waves will be constant in time.

I proceeded to use the new-to-me image registration code in MATLAB before reconstructing the surface height. Below are the still and moving images of the water I used.



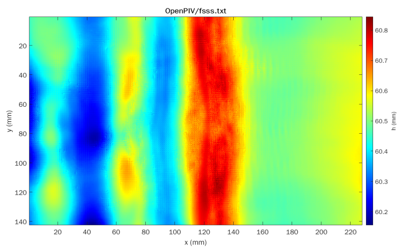
(a) Still Water



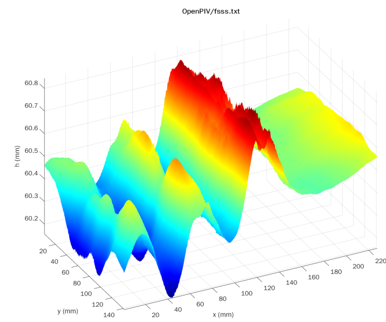
(b) Moving Water

Figure 16: Water Images Used in Software

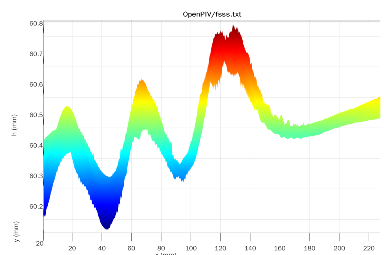
As you can see, the moving water doesn't have an excessively strong wave moving across it. If you look closely a plane wave is still present. The reason I chose this image for my moving water was because I wanted to make sure that the change in camera settings and water depth resulted in higher quality surface height reconstruction than earlier in this report.



(a) 2D (Above)



(b) 3D (Aerial)



(c) 3D (Side)

Figure 17: Surface Height Reconstruction

As you can see, the changes in my experimental setup resulted in higher quality surface height reconstructions. The problems present in the previous section aren't there, namely blurriness and an ineligible surface height reconstruction.

I would also like to point out that the weird slanting we noticed in my report containing the outdoor images is not present here. The lack of slanting might be a result of using a level for the glass tray and camera, making sure those planes are parallel.

The other observation is that the crest in 17b appears to have some noise, however, the shape of the wave is still very clear. The rest of the surface height reconstruction appears to be considerably smooth despite such a high resolution (sub-millimeter) image. This proves that the noise in the outdoor images near the shadows was indeed a result of the shadows, since no shadows are present here and also there is not nearly as much noise near the highest-amplitude wave.

I'm really happy with these results since this overcomes the obstacle of being able to take indoor images. This also completely removes the problem of noise as a result of shadows from lighting from above, justifying the cost of an LED panel.

1.8 15 Pixel Overlap

As mentioned in my last report, setting the overlap for an interrogation windows of 16 pixels higher results in smoother surface height reconstructions. This, however, fails when the overlap is set to 15 pixels because my computer crashes. So, I went into the lab and used one of the Macs to run the python code, since the Macs have 32GB of ram (more than both my laptop and desktop). The code ran successfully, albeit at a significantly larger run-time. The next obstacle, however, came from MATLAB which didn't want to display the surface height reconstruction for some reason. I got the Mac "ding" sound when something breaks every time I ran MATLAB. I did not have time to troubleshoot this problem in this report. The size of the file that MATLAB is reading from python is just under 219 MB.

2 Description of Next Steps

I overcame many problems in this report: blurry waves, shadows on the pattern, and slanting in the surface heights. The first two were systematically overcome, while the last one was not present in this report. The slanting might appear again in the future, however, my hypothesis is that it was a result of taking pictures outdoors and the ground and/or camera not being level.

My immediate next step is to figure out how to account for the glass tray's thickness in the software, whether it be in pivmat and/or OpenPIV. Afterwards, I believe helping with the acrylic piece would be a good next step, since I would be at the point where I need to calibrate FSSS. Otherwise, I can work on setting up the water table so that I can experiment with averaging multiple images together since the wave shape should be constant in time.

3 Questions

- What should I pursue after I figure out how to account for the glass-tray's thickness?
- Should I add a dimmer to the LED panel?
- Why do deeper waves travel faster and with shorter wavelengths in my glass tray?
- Any ideas why MATLAB doesn't want to work with the file output from the Python code on the Mac?