# DLA Report 4

Alexey Yermakov
19 October 2021

## 1 Description of what was done

### 1.1 Summary

We ordered parts for the water table. I also took more classes in the ITLL to gain access to various machines, including a CNC. I then tweaked some parameters in OpenPIV by using the images from my last report. I found a setting that increases smoothness at the cost of time and memory. This setting, however, doesn't remove the noise created by shadows. I also analyzed the indoor pictures I took the week of my last report and concluded they were not useful. There were human errors associated with those pictures so I decided to try again. The second round of indoor pictures were much more controlled, but still not very useful. I will try again, but this time use the LED panel in the hopes that the higher lumen output will solve some of my problems.

### 1.2 Parts Order

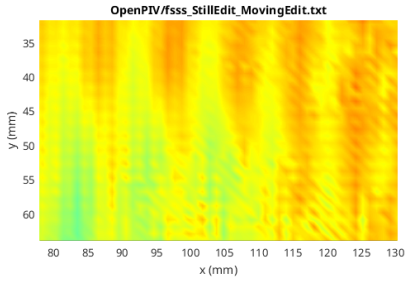
As a group we ordered a 12"x12"x1" piece of clear acrylic, an LED panel, Novus 3/2/1 Plastic Polish. The former two were delivered to Home Depot and I took the liberty to pick them up. The plastic polish was ordered through Amazon. Note that the LED panel was picked Friday 10/15, after which most of this report was completed, so I didn't have time to use the LED panel.

### 1.3 ITLL Classes

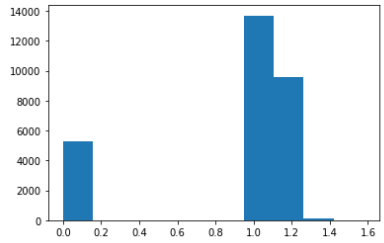
The week of October 11th, I two classes in the ITLL to gain access to more machines. The first class was to gain access to the 3-axis and 5-axis CNC machines. The second class was to gain access to the lathes and mills. The only other class I can see being useful would be for the laser cutters.

### 1.4 Tweaking Parameters Outdoor Images

I analyzed the changes in the resulting surface height by tweaking parameters in OpenPIV. I used a subset of the surface from the previous report as the surface. First, I modified `df_overlap`.

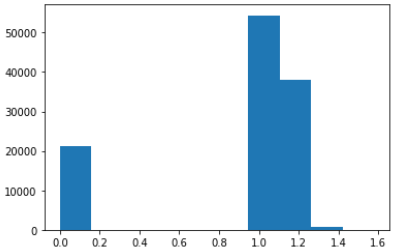



(a) `df_overlap=4` surface

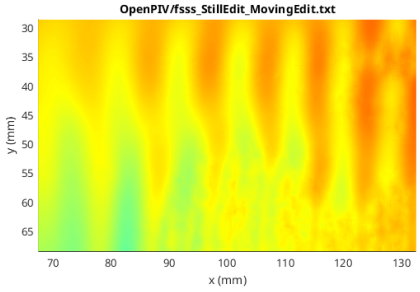


(b) `df_overlap=4` histogram

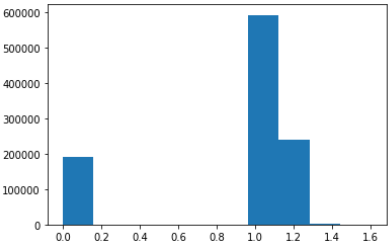

(c) `df_overlap=10` surface



(d) `df_overlap=10` histogram




(e) `df_overlap=14` surface

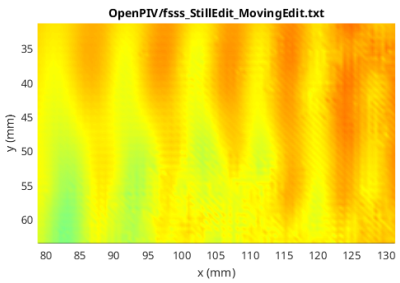


(f) `df_overlap=14` histogram

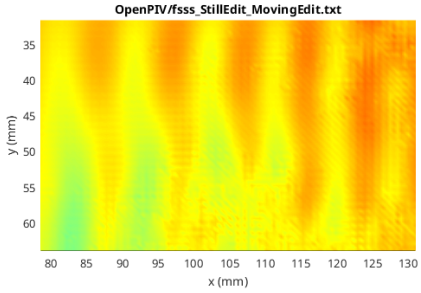
Figure 1: Surfaces and Histograms for various `df_overlap` values

It's clear that a higher value for `df_overlap` results in a smoother image. The histograms were mostly the same, though it's clear that the number of vectors is increasing.

I then analyzed different methods for filling in the displacement field vectors that were removed from the histograms. This method is called after the displacement field is generated, so the histograms generated are constant here.




(a) `localmean` method




(b) `disk` method

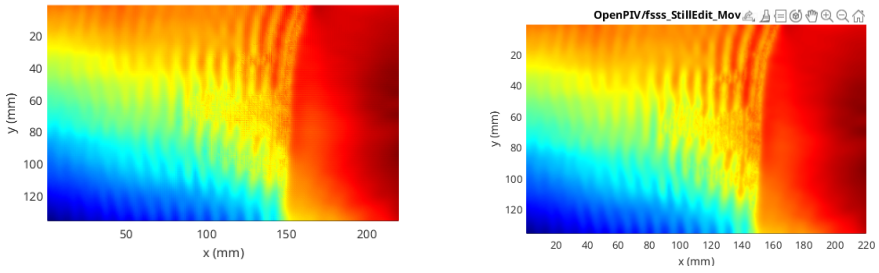

(c) `distance` method

Figure 2: Surfaces for various `replace_outliers` values

The different `replace_outliers` values resulted in no noticeable difference in image smoothness.

My findings show that an increase in `df_overlap` results in a smoother image. The downside is that the displacement field contains significantly more vectors, increasing computational time and memory consumption.

An interesting observation is that setting `df_overlap` to 15 caused Python to crash. Recall that my window size is 16 pixels squared. As a result, `df_overlap` is required to be less than 16. The largest integer less than 16 is 15, but I only got 14 to work as `df_overlap` before the software crashed.




(a) `df_overlap=10` surface (b) `df_overlap=14` surface

Figure 3: Comparison of noise between 10 and 14 pixel overlap

Despite the smoothing effect an increase of `df_overlap` has, it did not remove the noise experienced in the previous report in the regions containing shadows.

## 1.5 Analyzing Indoor Images

As mentioned in my last report, taking pictures outdoors generated noise likely because of the sun lighting the pattern, creating shadows. So, I took pictures indoors, illuminating the pattern from below. Out of the photos I took, I couldn't get any meaningful data. The still images I took had variations between them, even though I used software to take the pictures and didn't touch the camera. I also noticed that the glass tray was slanted because of being placed on top of the light box's diffusion paper. Lastly, the light box didn't illuminate the pattern evenly. As a result, I omit the images I created because they're not interesting and riddles with experimental errors.

I went back into the lab to take better pictures. The first thing I did was open up the light box and arrange the LED strip to be more uniform.

(a) Original

(b) Updated

(c) Updated with Light

Figure 4: Light Box Before and After Adjustments

As you can see, the LED strip was a jumbled mess, so adjusting its layout was necessary to improve image quality. However, even with the LED strip adjusted, you can still tell that the light isn't uniform. This is exactly why the LED panel will be helpful in the experimentation, since it provides uniform lighting.

The next thing I did was update the camera settings to the highest resolution, at 5472x3648 pixels. This required me to re-print the pattern with a higher density of dots. I used the same technique outlined in Report 4 where I looked at the output of the MATLAB script `makebospattern` after updating the source code to the appropriate camera resolution.

I then set up the experiment. I used the water table because the base of the table would allow the glass tray to be flat. I placed the updated pattern underneath the glass tray and atop the water table. I then taped the light box

to the bottom of the water table to illuminate the pattern under the glass tray. I also had to adjust the height of the water table so that the glass tray would be flat on the table. I attached the camera above the water table.

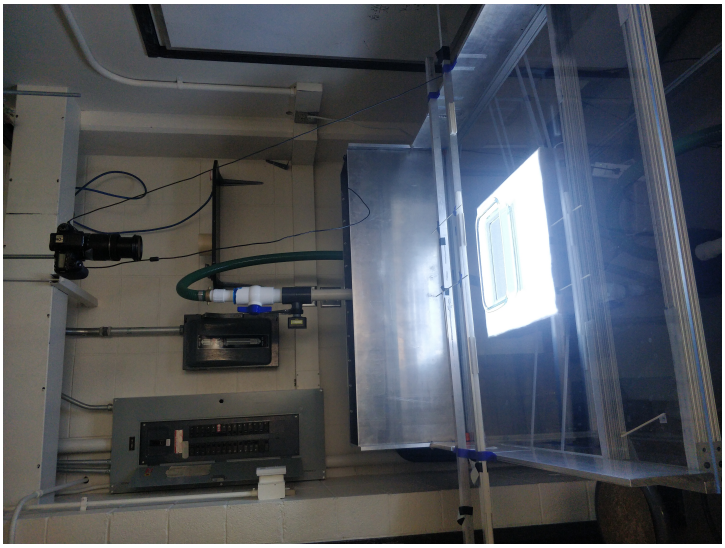
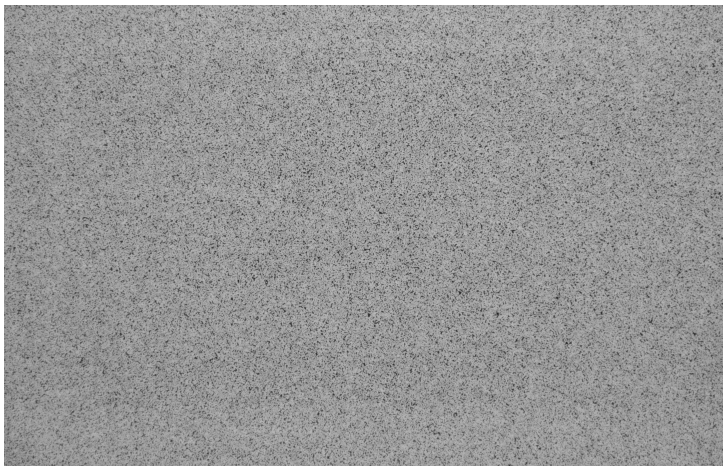


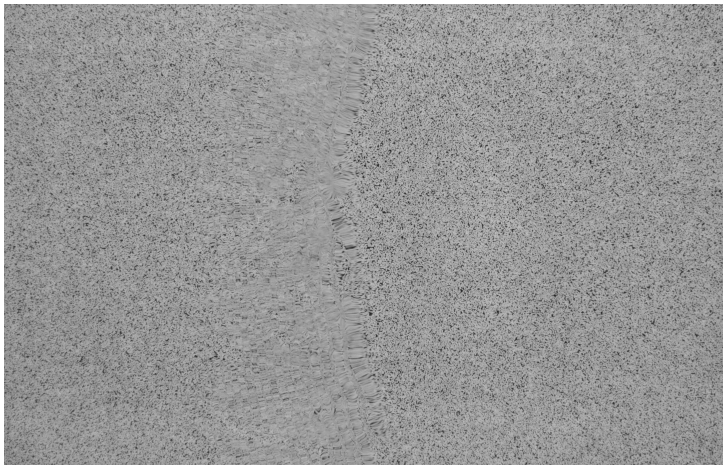
Figure 5: Experimental Set Up

I then took pictures of three separate trials.

The results are disappointing. I generated the wave the same way as in my previous report; however, the surface heights here were not nearly as crisp or defined.

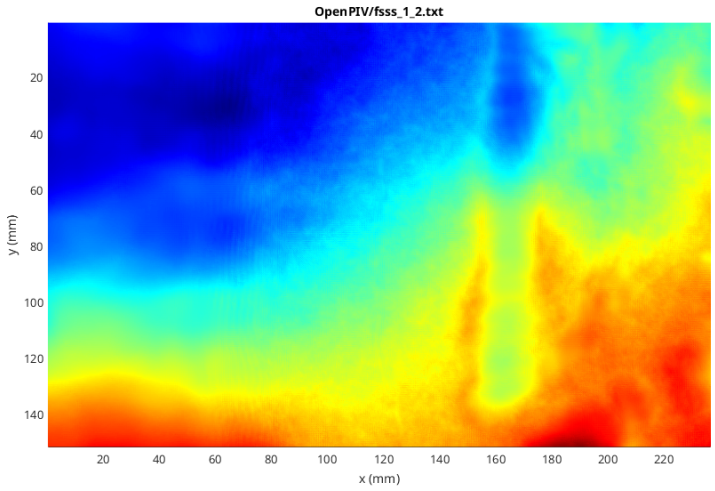


(a) Still Water

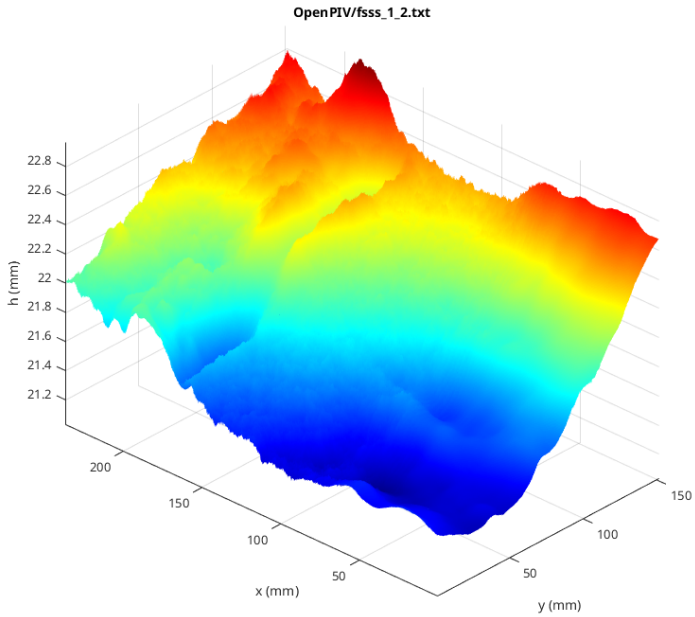


(b) Moving Water

Figure 6: Original photos used in software




(a) Top View




(b) Side View

Figure 7: Generated Surface Height

One positive from this result is that having the light source below the pattern removed the shadows generated by the waves. Another is that the LED box's uneven lighting didn't appear in the final images.

On the other hand, I am unable to verify if this reduces noise with these images because the surface height reconstruction isn't very trust-worthy. I ex-

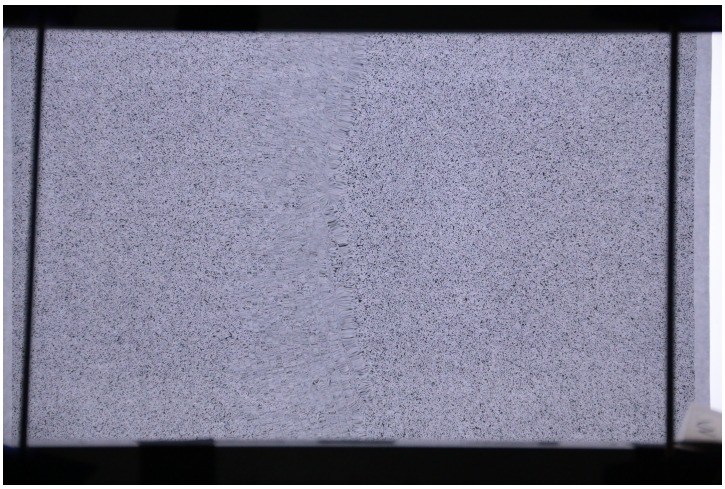
pected a similar wave pattern as with my fourth report since the wave was generated the same way. My primary suspect in the poor data is the shutter speed. When I took the pictures inside, I adjusted the camera settings to have the pattern visible and with high contrast. The settings I used were 1/640 shutter speed, 5.6 aperture, and 3200 ISO. I was under the impression that this shutter speed would accurately capture the water at one moment in time, but as you can see from 6b, the pattern where the water is moving is very blurry. This leads me to believe that the blurriness negatively affects the software used to reconstruct surface height.

Upon further investigation, I can retrieve the settings used by the camera for my previous report by analyzing the metadata of the raw image. It turns out that the outdoor pictures used 1/640 shutter speed, 10.0 aperture, and 100 ISO. So, the shutter speed was exactly the same! The biggest difference was ISO. When ISO is higher, the camera captures more light but results in grainier images. The indoor image was definitely grainier than the outdoor image, but I don't believe that could have caused the blurriness on the water wave. I am not sure why the wave was blurry. I'll have to try different camera settings with the LED panel to get a non-blurry image.

## 2 Description of Next Steps

The biggest challenge I need to overcome first is to have an experimental set-up that allows me to take high-quality, usable pictures indoors. This can be achieved with the help of new LED panel that I picked up. I will go into the lab, attach the LED panel to the bottom of the water table, and take more pictures in the hopes that the higher lumen output will give me better images.

I also need to rethink how I added markers to center the images. For some reason, even though I am taking pictures in software and am not moving anything but a computer mouse, the images are shifted/rotated compared to one another. Since I realized this in earlier reports, I attempted to fix this by adding markers in my images to help me align them. The way I did that here was by putting skewers above the glass tray.



(a) Top View

Figure 8: Full Image Example

As you can see from 8, the skewers are blurry since the camera is focusing on the pattern. Ideally, I would be able to place markers of some sort on the pattern to better align the images; however, I can't since the water on the tray will distort the markers. The other option is to have the markers outside of the glass tray on the same plane as the pattern. This will work, however, the usable resolution of the image with the pattern will be significantly reduced.

Finally, once I have a good set of images I need to hunt down the parameter for accounting for the glass base of the tray.

As mentioned previously, I will tackle the slanting in the final surface height reconstruction once I have an image of still water and an image of moving water that is free from errors.

I also need to ask an ITLL employee how much they would charge exactly to CNC the acrylic part Jeffrey made. He has a model that he sent me, so the ITLL should be able to give me a quote pretty easily.

# 3 Questions

- Is there a way to clean adhesive off the bottom of the water table?
- Should I sign up for a class to gain access to the laser cutters?
- Does anyone have any ideas with improving my experimental set-up?
  - How should I improve the way I align the images?
  - Is there a way to not have the camera move between images?
  - How do I get the pattern to not be blurry when a wave moves across it indoors?

- Is there a way I can laminate paper on campus?