DLA Report 2

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1 Description of what was done

1.1 Acrylic vs. Epoxy

During the previous team meeting, we brainstormed various solutions to test the FS-SS method. Those solutions consisted of machining acrylic, molding silicone, or using plain water to create waves with 10 mm wavelengths. We agreed that using water would be unpredictable and not serve us well to develop and calibrate FS-SS. Therefore, Jeffrey and I agreed to compare Acrylic and Epoxy independently and meet together to discuss which is better based on various criteria and weights. We decided to pursue acrylic. See **'Acrylic_vs_Epoxy'**.

1.2 Camera Settings Review

After deciding the material and process to use to construct the controlled environment for testing FS-SS, I continued developing and researching the FS-SS pattern. I downloaded and installed pivmat to my desktop and laptop along with MATLAB itself. I then generated two sample patterns to print on a standard sheet of paper. I then analyzed Enkhlen Amarsanaa's work on the best camera settings for FS-SS. In their file titled **'Eny Weekly Report.docx'** they claim that the MATLAB function *brisque* scores the images **LEDBox.png** and **NoLEDBox.png** the same. Their code, which I modified slightly to work with a newer version of MATLAB:

```
% LED box
picon = imread('./Pictures/LEDbox.png');
picoff = imread('./Pictures/NoLEDbox.png');
[picon,Rect] = imcrop(picon);
picoff = imcrop(picoff,Rect);
brisqueon = brisque(picon)
brisqueoff = brisque(picoff)
```

produces the following result:

```
brisqueon =
   43.4582

brisqueoff =
   38.9767
```

which implies that their results in the report were not accurate. Furthermore, the darker image (**brisqueoff**) scored better (lower scores mean better quality), which is counter-intuitive to what we'd expect. We expect that the image with a backlight on the pattern would score better since the pattern is more visible. Counter-intuitive results happened when using the **niqe** function in Enkhlen's report as well:

```
brisqueon =
   41.8520

brisqueoff =
    7.2540
```

This can happen for many reasons. My intuition tells me that brighter images mean the image is more uniform in color resulting in a better score. As a result, the images which have higher contrast are scored worse. I attempted to use **niqe** and **brisque** on uniform white and black rectangles, but errors were thrown by the functions since they detected their constant uniformity. These findings push me to research camera settings myself to determine what is best for FS-SS.

1.3 ITLL Machine Shop Training

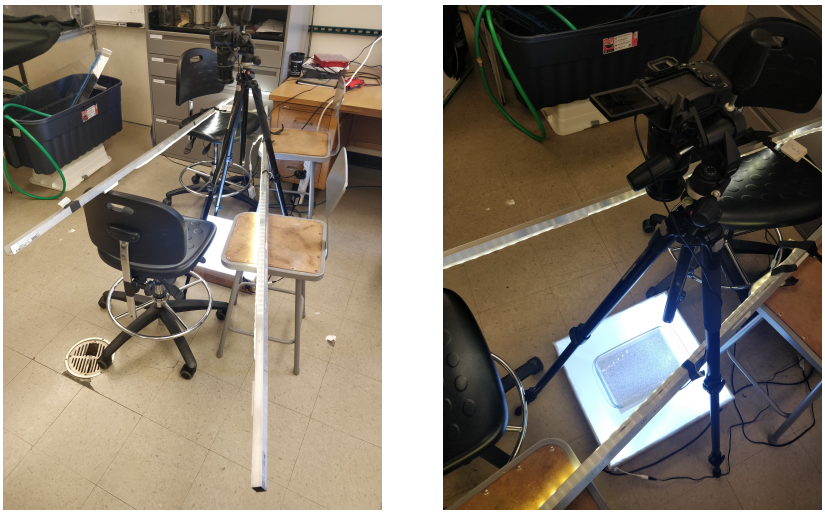
Mark took the liberty to sign me up for a machine shop class in the Duane Physics building. This class, however, runs the second week of November, which is more than a month out. As a result, I decided to look into the machine shop in the ITLL. In doing so, I found that machining classes were available much sooner, so I took a Saws + Drills course in addition to a 3D printing course. I have also registered for a Mills + Lathes course, which was only available October 15th.

One of the employees at the ITLL's machine shop is Cameron Miksch (Manufacturing Specialist) (cameron.miksch@colorado.edu). He told me that CNC machine classes will soon be available. I also asked him about how much it would cost to machine a 6"x6" piece of acrylic to contain plane waves with 1mm wavelength. He told me that a rough estimate would be $300. This seems like a lot of money just for performing a proof of concept of FSSS, so I will proceed with working on FSSS with the glass tray we have in the lab by filling it up with water until we discuss this development as a group.

Note that the ITLL charges for research projects but not club or personal projects.

1.4 FSSS Images

First, I tried printing some more patterns. However, I went in on a Sunday and it appears that the 2nd floor ECOT printer was closed for the weekend. This required me to use patterns we had already printed.



(a) Side view (b) Top-down view

Figure 1: Experimental set-up

I then went into the lab in Duane physics to start taking pictures of water in the glass tray before trying to use OpenPIV and pivmat. I set up a camera on a tripod facing directly down. Under the camera, on the ground, was the glass tray containing water with the printed pattern below it. See 1.

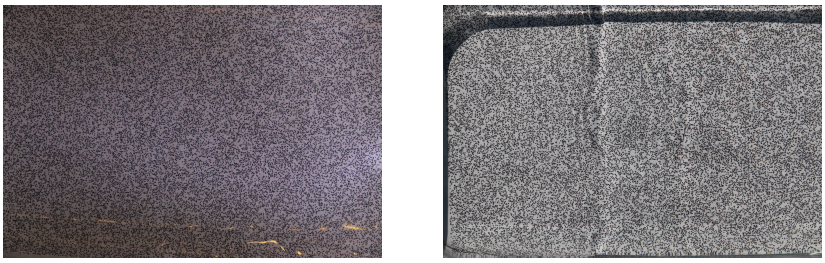
The first thing I noticed was that there was much less purple discoloration than in Enkhlen's report on camera settings. The second thing I noticed was that even with the light-box and two LED strips illuminating the pattern used for FS-SS, the images were a bit dark. I tried a mix of custom settings (messing around with f-stop and ISO) along with having the camera in automatic mode, but could not improve the brightness of the image. I then went outside (around 2:00pm on a clear day) and took pictures in the sunlight with the camera in automatic. The results were immediately better. See 2.

While cropping the images, I noticed that the pattern moved between photos. This is a result of me not taping down the pattern and generating a wave by moving the glass tray. In the future, I need to generate waves without moving the glass tray, pattern, or camera. This will ensure the resulting images are centered and reduce human errors. I believe I introduced human error because I aligned the two images I used in the software manually.

Another thing I noticed, is that the cropped images have higher pixel density than the original images after cropping them in Inkscape (the graphics editor I used). This is not what I expected to happen. I now had two images to use in OpenPIV and pivmat (see 3).

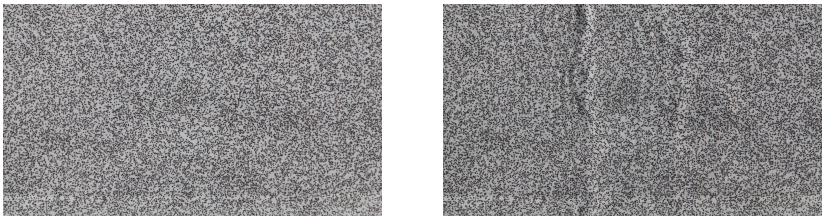
I then began working on generating a displacement field using OpenPIV.

I found an FS-SS page by the FS-SS paper author that describes in more



(a) Pattern inside (b) Pattern outside

Figure 2: Pattern images lighting comparison



(a) Still Water (b) Moving Water

Figure 3: Pattern images used in software

detail the method for generating the displacement field and surface height. The important take-away for the pattern is that we need "At least 5 dots ('particles') per interrogation window (IW)" of size "16x16 pixels, and contain dots of diameter 2-5 pixels, with displacements of order of 5 pixels". The pattern I am using requires the interrogation windows to be 200x200 pixels in order to contain at least 5 dots, whose diameter is more than 30 pixels.

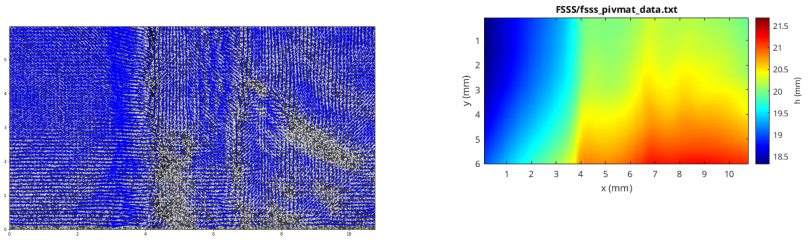
I then followed an OpenPIV tutorial to create a vector field.

After messing around with various parameters (those of which I still don't fully understand), I got a decent vector field image. I then followed the aforementioned FS-SS page to construct the surface height from the images I took. See 4 for both graphics.

The result looks very promising. The water heights are clearly wrong: I had a single plane wave in the center-left of the tray moving right to left; Also, the height differences were smaller in the reconstruction than in reality (approximately 2x smaller at 1.5mm than 3mm in reality). Despite these problems, the significant structures are present.

I believe that the height differences were partially a result of my manual cropping. This can be alleviated by not moving the glass tray, pattern, and camera.

Anyways, I am glad I was able to use the software available to me for free instead of having to pay for software and/or develop my own.



(a) Displacement Field (b) Reconstructed Surface

Figure 4: Software Generated Graphics

2 Description of next steps

Next, I need to look into why Inkscape up-scaled the pixel density for the images I cropped. I also need to look into various light boxes to use for the water table, since it's safe to assume we won't be moving the water table outside for experiments. Indoor lighting is currently insufficient and produces dim images. I also need to produce a pattern that satisfies the requirements I mentioned above (we need "At least 5 dots ('particles') per interrogation window (IW)" of size "16x16 pixels, and contain dots of diameter 2-5 pixels, with displacements of order of 5 pixels"). This will then require me to re-take pictures to then use in OpenPIV and pivmat. I also need to better understand the various parameters OpenPIV and pivmat accept in order to reduce any human error.

With the group, we need to discuss our FS-SS calibration method and whether or not a $300 block of machined acrylic is worth it.

3 Questions

- Do I have access to the printer in ECOT 2XX during the weekends? I tried going in on September 19th and all the doors were locked.