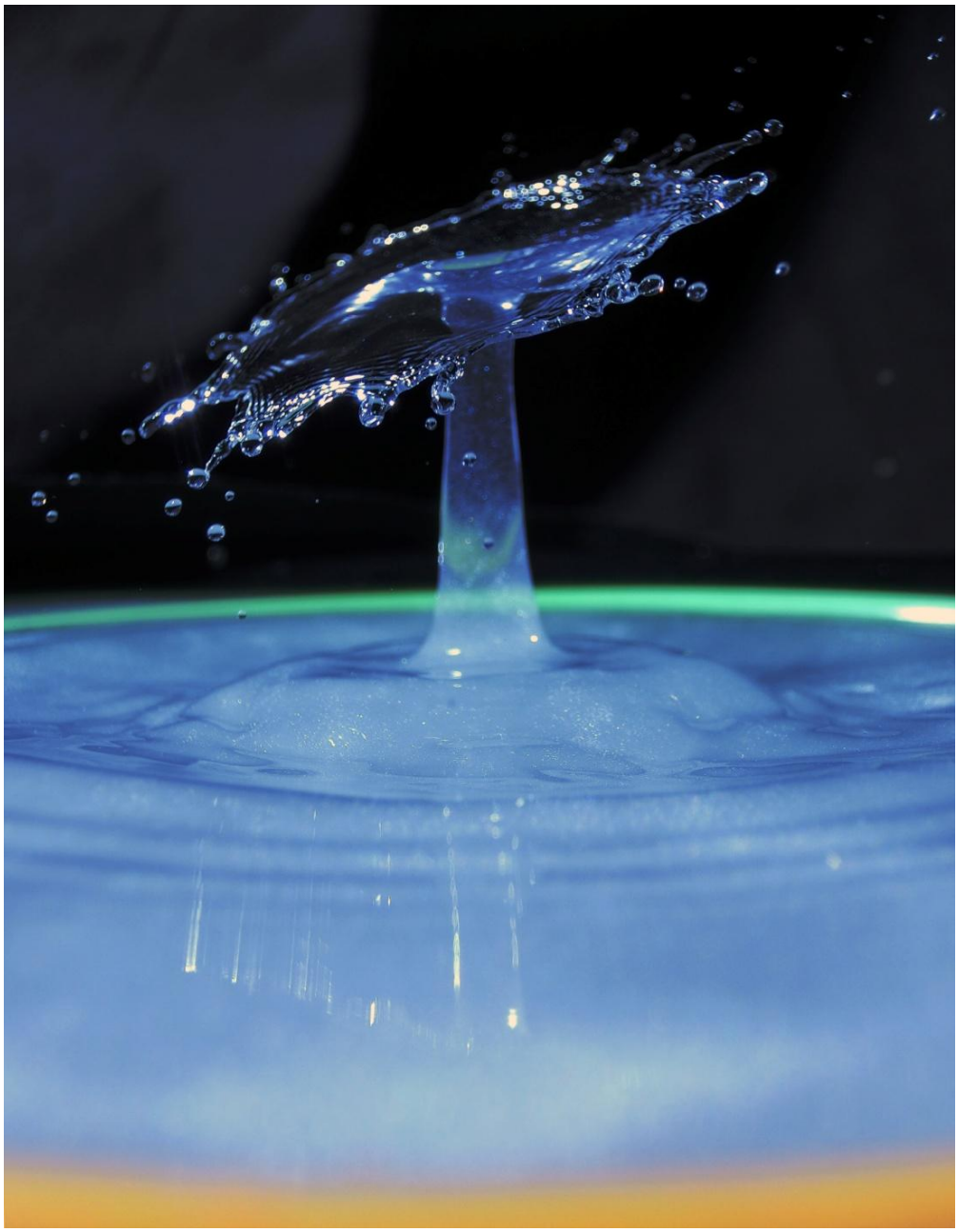
The Last Drop in the Bucket

Group Assignment Report #3



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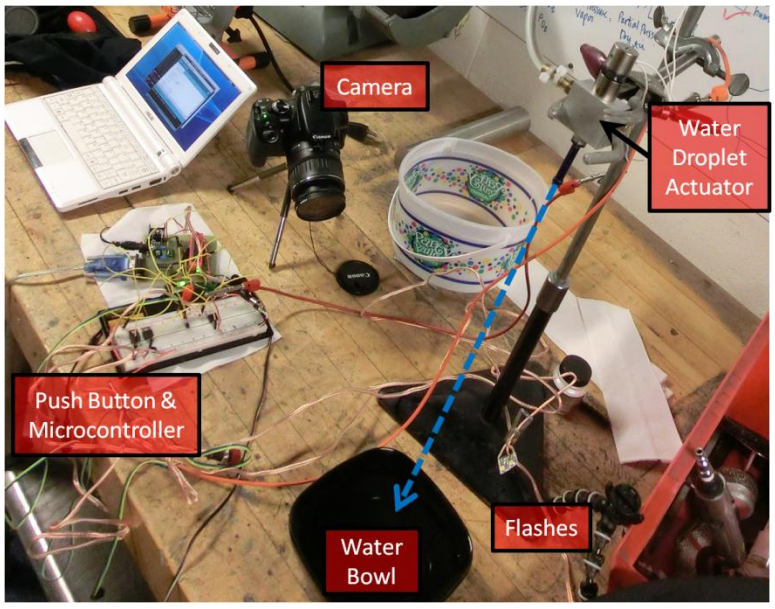
Purpose

This image was created for the CU Boulder Mechanical Engineering course MCEN 4151 Flow Visualization "Group 3" assignment. The intent of this assignment was to work within a random group composed of students from different backgrounds and experience levels, relying on each other to help visualize a desired flow phenomenon. Our team composed of Paul Sweazey, Wayne Russell, Gabriel Bershenyi, Blake Buchannan, and Zach Wehner decided to focus on the flow phenomenon created by water droplets impacting each other above a body of water.

Flow Apparatus

The apparatus (below) we assembled to create and control the flow phenomenon utilized a microcontroller controlling a camera, a water droplet actuator, and flashes. The microcontroller was programmed to send a signal to all of these devices according to where the user wanted to have their image capture the water droplet. The water droplet actuator was held about two feet above a black water bowl where the droplets were to impact. The actuator was perfectly timed to send two droplets; the first hit the water in the bowl and began to rebound up as the second drop collided with it. The result was a split second flow where the water spread out in to a thin flat flow perpendicular to the droplets original flow path. It was this split second in which the camera flashes were programmed to go off and capture the flow as well.



An interesting aspect about having this amount of control was that the user could define almost every aspect of the flow phenomenon as well as have a relatively repeatable result time after time. Also this set up allowed for having multiple flashes going off from different angles at different times allowing for multiple exposures and effects in one image. The resulting flow phenomenon captured was extremely interesting from the fact that there was so much going on at a physical flow level. A brief list of forces/phenomena involved include; gravitational, shear, surface tension, momentum, and Rayleigh Plesset instability [1].

Visualization Technique

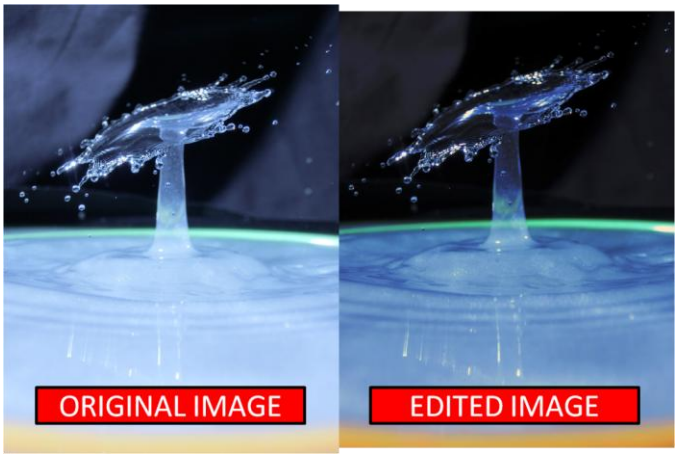
As the team and I began the shoot we found that the background of the room we were in was a bit distracting to the phenomenon. To remove this distraction we decided to eliminate all of the light in the room and let the camera flashes be the primary light source. This also eliminated the need to shoot with a high shutter rate and allow the flash alone expose the image. Also we hung a black sheet behind the flow to block any other distracting elements from being observed. To add some color to the image glow sticks were submerged in to the water, which also gave some depth to the flat water.

Another technique employed to better visualize the flow was the addition of PearEx to the water in the bowl. This addition allowed the image to visualize the particle aspect of the flow more thoroughly as it gave small white reference points within the flow as it moved and mixed. A draw back from using the PearlEx was the fact that it picked up and reflected the light from the flash very well, in turn over exposing the water a bit.

Photographic Technique

The camera used to take this image was a high speed Casio EX-ZR100 set in manual mode to allow for control of Focus, ISO, Aperture, and Exposure time. Since we were shooting in a low light situation and I wanted the clearest image possible, the ISO was set to a low value of 100. As for the F-stop, it was set to f/4.4 to shorten the depth of field and blur out part of the phenomenon giving the image depth. The focus was fairly close at 9mm which helped with the detail and stability of the image. Also after some playing around I set the exposure to 1.3 seconds, which allowed the camera to collect enough light from the dim glow sticks to include some of their color in the final image. Though with this exposure one would think that the water would be blurry, it was actually the quick burst of light from the flash that froze the phenomenon in the image. The camera's maximum resolution of 3000 x 4000 was selected to provide as much detail possible.

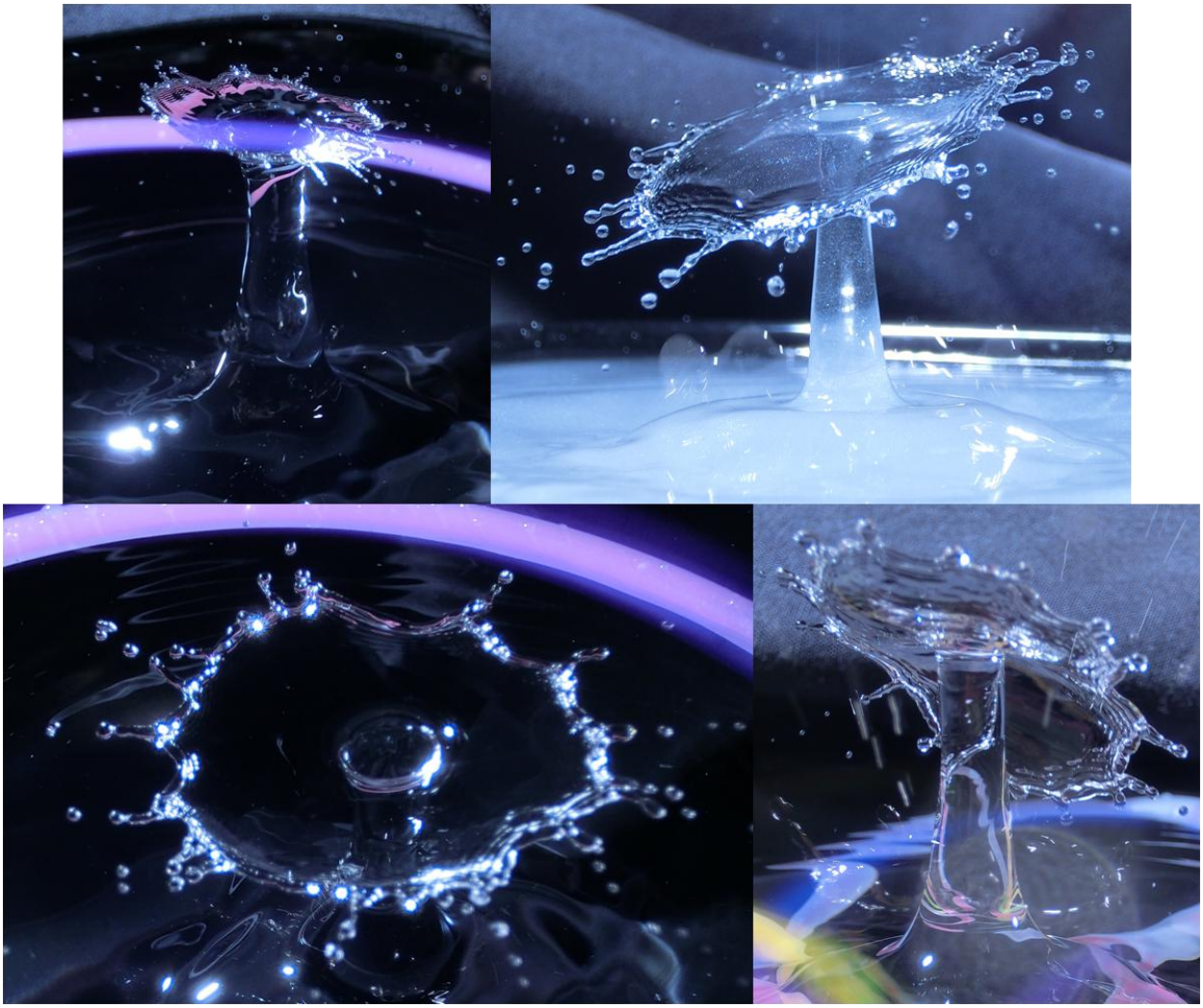
As post processing goes I spent a good amount of time in Photoshop attempting to highlight different aspects of the flow and add some artistic effect. One issue touched earlier was that the PearlEx/Water mix over exposed while the flow was fairly well exposed. This issue was countered by spending some time modifying the curves of the image eventually finding a balance of exposures. This method was also used to bring out the color of the glow sticks and darken the background. A bit of the original image was cropped out as well. Below is a side by side comparison of my final and edited image.



Reflection

In the end, I really enjoyed how my image turned out and feel it completely fulfilled my intent. I believe the image outlines the fluid physics well. I am curious about the instability involved, but unfortunately didn't have the time to explore them further. If I were to develop this idea further I would like to machine a nozzle on the water droplet actuator that released multiple droplets at once allowing multiple collisions to occur simultaneously contrasting each other in a single image.

As a closing comment, one of the most difficult aspects of this project was the fact that I captured so many amazing images, below I show a couple of the great images I had to abandon due to the fact that I could only choose one in the end.



[1] "Rayleigh–Plesset Equation." Wikipedia. Wikimedia Foundation, 29 Mar. 2013. Web. 30 Apr. 2013.