UNIVERSITY OF COLORADO - BOULDER

Flow Visualization

Team Project #2

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The purpose of the "Team Project #2" assignment was to work with our team members and capture an image that clearly exhibits the fluid dynamic phenomenon being observed. The group aspect of the project encourages communication and allows students to attempt to image more complex fluid phenomena's. This image was created for Professor Jean Hertzberg's flow visualization course at the University of Colorado in the spring of 2012. The original intent of the image was to use a combination of two fluids to create the Saffman-Taylor instability. By doing so, we hoped to capture an interesting viscous fingering pattern of two fluids over a black light. However, after producing unimpressive results, it was decided to try a different approach. The chosen image captures a combination of maple syrup, Tide detergent/water mixture, and highlighter/water mixture as it is laid over a white acrylic board. Specifically, the image displays the behavior of the spreading viscous layers, illustrating the Marangoni effect.

In order to produce the image, a dark ambiance was created in the light and vibrations room of the ITLL by turning off all of the surrounding lights and placing two 36 watt black lights 1/8 inch below the fluid mixture. On top of the black lights was a 1/8 inch thick white acrylic board. The fluids used to create the fluid phenomenon were maple syrup, Tide detergent/water mixture, and a highlighter/water mixture. To create the layering of the fluids 2 tablespoons of maple syrup was placed on top of the white acrylic board. Next, 1 tablespoon of a 50-50 Tide detergent and water mixture was placed on top of the maple syrup. Finally, 3 syringe drops of a 50-50 yellow highlighter fluid and water mixture were placed in the center of the tide and maple syrup layers. The camera was held straight above the fluid mixture at a distance of about 3 inches from object to lens. Figure 1 and 2 below shows the set up that created the final image.

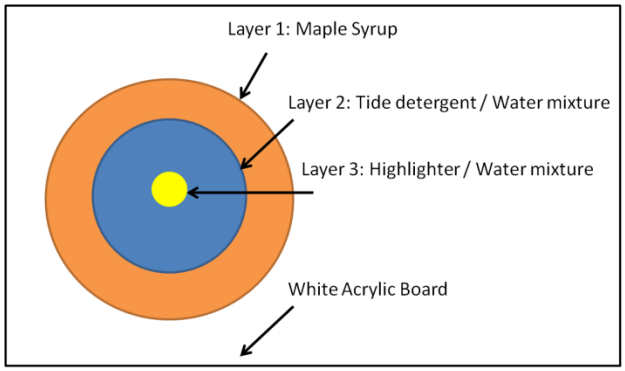

Figure 1: Top view of the final image setup

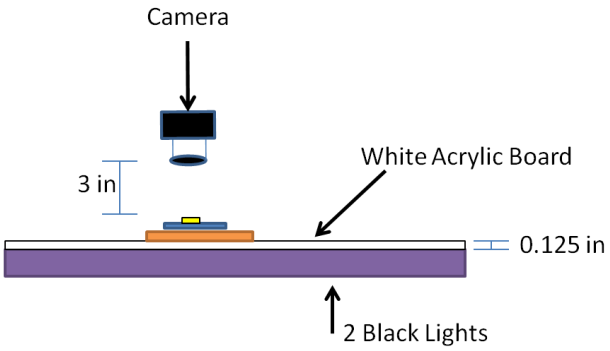

Figure 2: Side view of the final image setup

The Marangoni effect is caused when a liquid with a high surface tension pulls harder on the surrounding liquid than a liquid with a low surface tension [1]. Due to this, the liquid ends up shearing in proportion to the local surface concentration gradient [2]. For the production of this image, the first layer of maple syrup had a higher surface tension gradient then the next layer of the Tide detergent/ water. Along the same lines, the second layer of Tide detergent/water had a higher surface tension gradient then the third layer of highlighter/water. Due to this, when the Tide detergent/water was placed on top of the syrup it was pulled out from the center, creating the viscous fingering present in the image. Additionally, the highlighter/water was pulled out from the center of the bottom two layers.

This is especially visible in the first image, where you can see that all of the highlighter/water had been sheared off into the bottom left corner of the image.

The visualization technique used to capture the final image was the spreading of a surfactant solution on a thin viscous film, illustrating the Marangoni effect [2]. The fluids used in creating this effect was a combination of maple syrup, Tide detergent, and highlighter fluid. In order to make these combinations of fluid visible, they were poured on top of a white acrylic layer, which rested on top of two black lights. In order to get the bright vivid colors present in the image, the correct lighting was critical in capturing this fluid phenomenon. The lighting was produced by two 36 watt black lights that were positioned 1/8 inch below the fluid mixture. Additionally, the flash on the camera was not used in order to prevent saturation of the black lights. Further room preparation consisted of turning off all of the surrounding lights and closing all of the doors so that the room would be as dark as possible. The air temperature of the room was approximately 73°F.

The field of view of the original image was approximately 6 inches (wide) by 4 inches (height). A Sony DSLR-A230 digital camera was held straight above the fluid mixture at a distance of about 3 inches from object to lens. This provided an ideal viewing angle of the Marangoni effect because it allowed the photographer to see all of the shearing liquid effects that occurred as well as the elaborate viscous fingering that became visible. Since the fluid was moving slowly, motion blur was not a problem and as a result the camera was held stationary by the photographer without a tripod. This orientation created an original image with pixel dimensions of 3872 x 2592. The final pixel dimensions were 2696 x 2368 after being cropped in Gimp. In order to attain a clear image the aperture was set to f/5.6 and a corresponding shutter speed of 1/20 sec was chosen by the camera to allow for sufficient light to enter the lens. Additionally, the image was taken with an ISO setting of 400, ensuring a clear capture of the Marangoni effect in the low light setting. Furthermore, the focal length of the lens was 50mm. The original image before being edited in Gimp can be seen in figure 3 below.

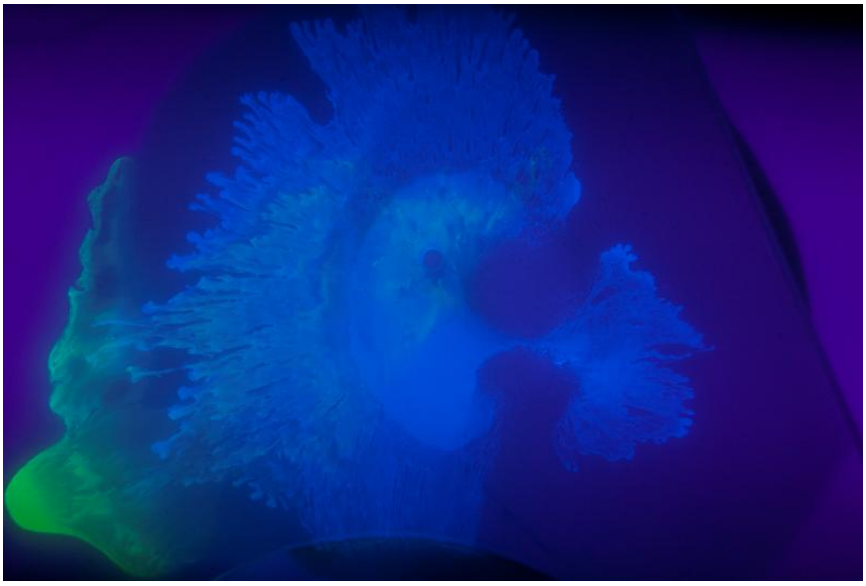

Figure 3: Original image before editing

After the original image was captured it was imported to Gimp and converted from RAW to a TIF file so that the image would maintain its format. The original image was then significantly cropped in Gimp to focus on the blue fingering that occurred between the fluid layers. Additionally, the curves tool was extensively used to brighten the blue Tide detergent and darken the purple of the black light to blacks. The image was then enhanced by using the clone stamp tool to blend any blemishes created by gaps in the spreading Tide detergent. Finally, the image was then enhanced with the unsharp mask tool to create a sharper overall image. The final edited image can be seen in figure 4 below.

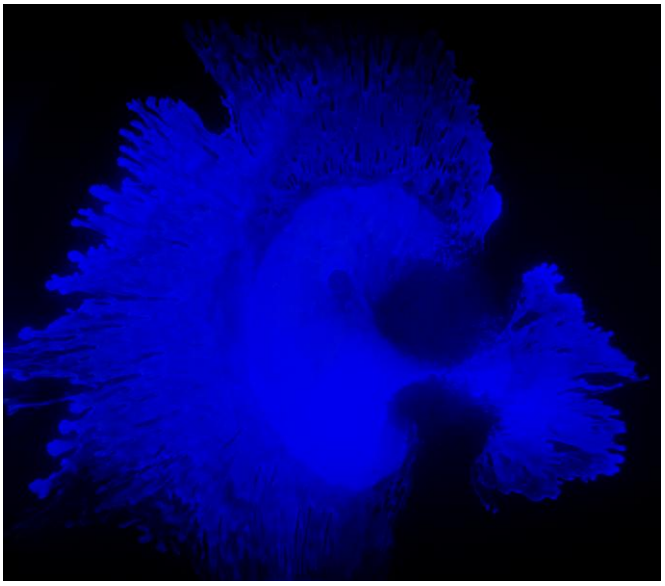

Figure 4: Final edited image

Ultimately, the image reveals the spreading of a surfactant solution on a thin viscous film, displaying the Marangoni effect. By cropping the image and extensively modifying the curves, I was able to create an image that is especially beautiful and intriguing to look at because it makes you wonder how this shape occurred. I really like the clarity of the fluid as well as the great contrast between the black background and the blue Tide detergent. I also like the shape that the fluid formed. It gives an appearance of a crescent moon shaped face spraying a jet out of its nose. However, because the black lights put out a purple glow the curves tool had to be used extensively so that the background would become black. This ended up decreasing the brightness of the fluids edges, revealing less effects of viscous fingering. If the group were to do this again, we would experiment with a wider variety of fluids and experiment in a room with no windows, so that less natural light would illuminate the fluid. This would ultimately allow for an even brighter contrast in colors between the fluid layers.

Works Cited:

[1] "Marangoni Effect." *Wikipedia*. Wikimedia Foundation, 03 Oct. 2012. Web. 05 Apr. 2012. <http://en.wikipedia.org/wiki/Marangoni_effect>.

[2] Darhuber. “Marangoni Driven Structures in Thin Film Flows.” *Physics of Fluids* 15, no. 9 (September 2003): S9.