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MCEN 4151
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Team Third – Spring 2018

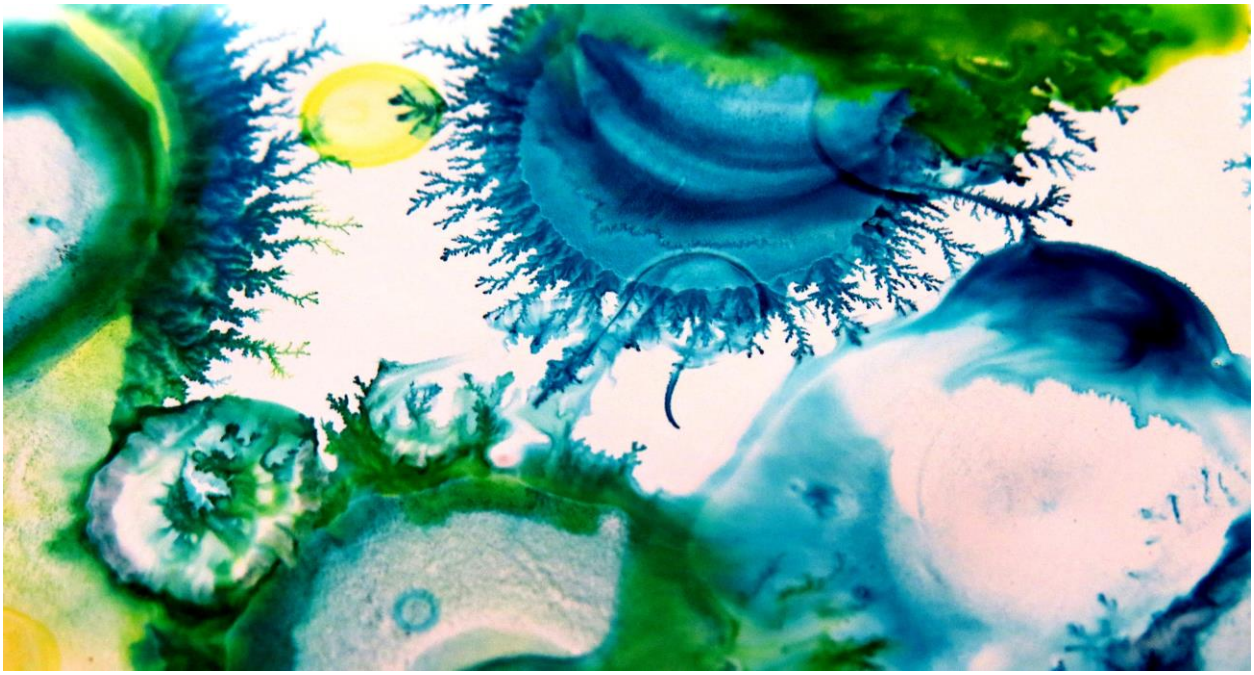

Figure 1: Final Image

Context:

The team third assignment is the last group project of the semester. The aim is, as a group, to capture detailed flow visualizations with more elaborate setups. Observed in Figure 1 is the final image, where acrylic dyed alcohol is interacting with acrylic paint. This is the one of the sharper images of the fingering effect at the edges of the die surface. With help from teammate, Jordan Nahabetian, we captured the surface effects of a Marangoni flow between two materials with varying surface tension.

Apparatus:

The phenomenon being observed in Figure 1 appears to be some variety of Marangoni flow interaction between alcohol and acrylic. However, this experiment is interesting because the fluid flow does not solely appear to exhibit the effects of surface tension. The branches extending off the dye are likely dendritic shaped formations driven by particulate interaction and a surface tension gradient. Because alcohol is a surfactant, it is the initial catalyst for the fractal propagation but there also may be a component of crystal growth driven by diffusion of solute atoms to the interface [2]. Additionally, this experiment is visualized with the coffee ring effect, or leaving a pattern after a particle-laden liquid evaporates [1]. Because of the particulates in the acrylic dye, when the isopropyl alcohol evaporates from the acrylic paint, it leaves behind the coloring that is seen in Figure 1.

Materials tend to produce dendritic crystals because it is a natural fractal pattern [4]. Fractals are easily understandable in an artistic sense, but is much harder to quantify mathematically. It is akin to a recursive formula, where the features are replicated, exhibiting similar patterns at increasingly smaller scales. The shape is produced by faster growth along energetically favorable crystallographic directions

[3]. Similar to the way water takes the path of least resistance, the alcohol dye mixture in this experiment branches out with regard to energetically favorable directions.

In terms of analyzing the system, the main indicator for the system would likely be easiest to quantify with the Marangoni number given by

$$Ma = -\frac{d\gamma}{dT}\frac{L\Delta T}{\mu\alpha}, \quad (1)$$

Where γ is surface tension, L is the characteristic length, α is thermal diffusivity, μ is dynamic viscosity, ΔT is the temperature difference. This number is a representation of the surface tension forces compared to the viscous forces of the system [5]. Although for this system I would expect the number to be on the order of magnitude of 1 or 2. The Marangoni flow is primarily driven by surface tension, although the branching finger effect may be caused by some part of viscous interaction.

In terms of setup, it was not a difficult setup to configure. The main staging for the experiment was in the basement of the ITLL on the small white photographic stage used for product design displays. Overhead were two florescent lights with a reflective white overhang. Additional paper reflectors were used to center as much light as possible on the subject. The schematic below gives a visual representation of the setup.

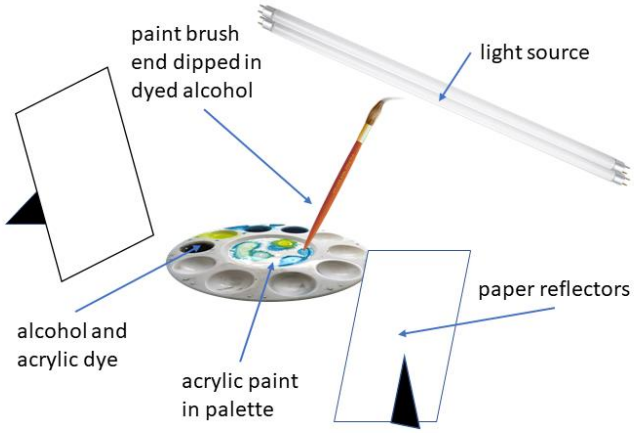

Figure 2: Setup Schematic

Visualization technique:

To get the effect visualized in Figure 1, we used *DecoArt Crafter's Acrylic* white acrylic paint mixed with water at a ratio of 1:4 to slightly decrease the viscosity of the acrylic and allow for the Alcohol ink to diffuse easier. This mixture was poured in the center of the palette as the base layer of the experiment. The driving surfactant of the flow is 91% isopropyl alcohol mixed with blue and yellow *Liquitex Acrylic Ink* at a ratio of 2:1. To begin the flow, the end of a paint brush was dipped into the mixtures, held in the surrounding trays of the palette, and then dropped into the white acrylic base. My teammate and I alternated between dropping the dyed alcohol and imaging the fingering phenomenon. After the Marangoni flow commenced, and the dye solidified in the paint, I added droplets of alcohol to get

additional blurring of the colors. The spots can be easily seen against the acrylic, creating a similar effect to when a water drop is smeared on an ink photograph.

Photographic Technique:

The original photo shown in figure is 4000 pixels x 3000 pixels. The camera used is a Canon PowerShot SX50 HS. The camera was hand held, about two inches away from the subject, and facing downward at about 70 degrees below horizontal. The image was taken in the ITLL basement on the white display photograph apparatus. Due to the depth of the counter, a large tripod could not be used. The camera specifications are an ISO-200, an aperture of f/5 and a shutter speed of 1/100 s. The focal length was 12.5mm, and the field of view is approximately 2 inches across. The image was adjusted in post processing using Gimp. The size of the initial image was cropped to dimensions of 4000x2134 pixels to remove the reflecting light in the upper left corner, and put emphasis at the focused portion of the image. The color curves were adjusted to bring up brightness and contrast to make the colors sharper. As seen below in Figure 3, the image is initially quite dim.

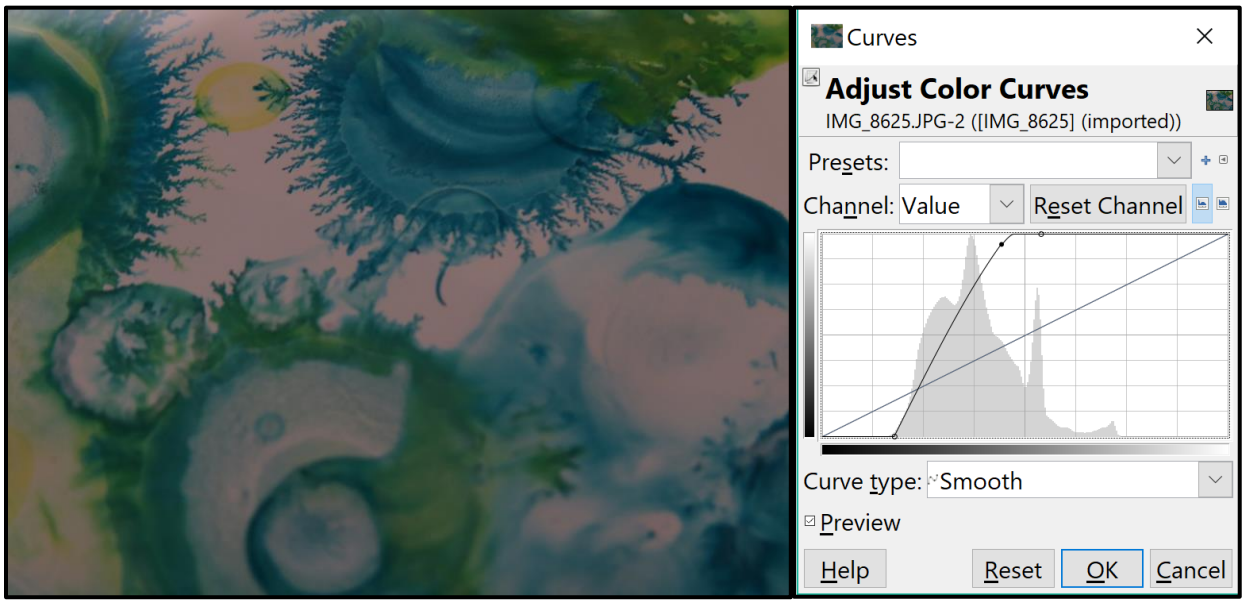

Figure 3: Original Image

Critique:

The final image portrays an interesting phenomenon, but I am still unsure whether the flow should be classified as a Marangoni flow instead of a Sauffman-Taylor instability, or if there were any chemical interaction to produce crystal growth. Additionally, although the desired effect was reproduced, there is most likely a better ratio of mixture of alcohol to dye depending on the dye coloring. The yellow die, although made with the same ratio, produced vastly different results from the blue die. In terms of photographic composition, the exposure and focus are well resolved. The edges are sharp at the region of focus, and there does not appear to be any blurring due to the time resolution of the camera. Overall, I am pleased with the image quality, but would like to understand more about the fluid flow being observed, and why the fractals appear in this medium. Inspiration for this experiment came from *Myriam's Nature* and her technique for creating fractals in acrylic paint.

References:

[1] Coffee Ring Effect. (27 April 2018). Accessed May 2, 2018, from https://en.wikipedia.org/wiki/Coffee_ring_effect

[2] Dendrite (crystal). (9 January 2018). Accessed May 2, 2018, from https://en.wikipedia.org/wiki/Dendrite_(crystal)

[3] Dendrite (metal). (24 April 2018). Accessed May 2, 2018 from https://en.wikipedia.org/wiki/Dendrite_(metal)

[4] Fractal. (30 April 2018). Accessed May 2, 2018, from https://en.wikipedia.org/wiki/Fractal

[5] Interfacial Phenomena. (3 June 2013). Accessed May 2, 2018, from https://ocw.mit.edu/courses/mathematics/18-357-interfacial-phenomena-fall-2010/lecture-notes/MIT18_357F10_lec_all.pdf