MCEN-4228-010

Flow Visualization

Group Report 03

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Appendix

1. Introduction

The purpose of the Group Phi's final project was to capture flow phenomena without using fluids. The original idea was to create and capture an image that had never been performed by any other classes prior to the spring 2009 semester. The group decided to capture human flow around static objects. This simple idea proved difficult to visualize due to the lack of "flow" in a single photograph; it was decided that a three dimensional time lapse video best resemble "flow" of humans around a static object. The time lapse photographs were taken on April 20, 2009 due to the high volume of pedestrian traffic near the Norlin Quadrangle on the University of Colorado at Boulder campus. As an added feature, the group utilized a stereoscopic camera apparatus, which rendered 3-D images of the flow phenomenon.

2. Flow Apparatus

The time lapse photos were captured at the walkway between Cristol Chemistry and Biochemistry and Ekeley Sciences buildings. The cameras were set up on the third floor of the chemistry building and pointed at the three to five people (the walkway obstacles) in yellow hats standing abreast, approximately 41^{o} from the horizon. The obstacles were standing about 10.7 meters below and 12.2 meters out from the camera. A diagram of the flow apparatus and photo-shoot setup is shown in Figure 1. The cameras were operating from 3:30PM to 4:10PM. The goal of this setup was to force pedestrian traffic off its original path to avoid colliding with the obstacles in the walkway. Sociological and psychological reasons for this observed behavior are described in the Physics Analysis section.

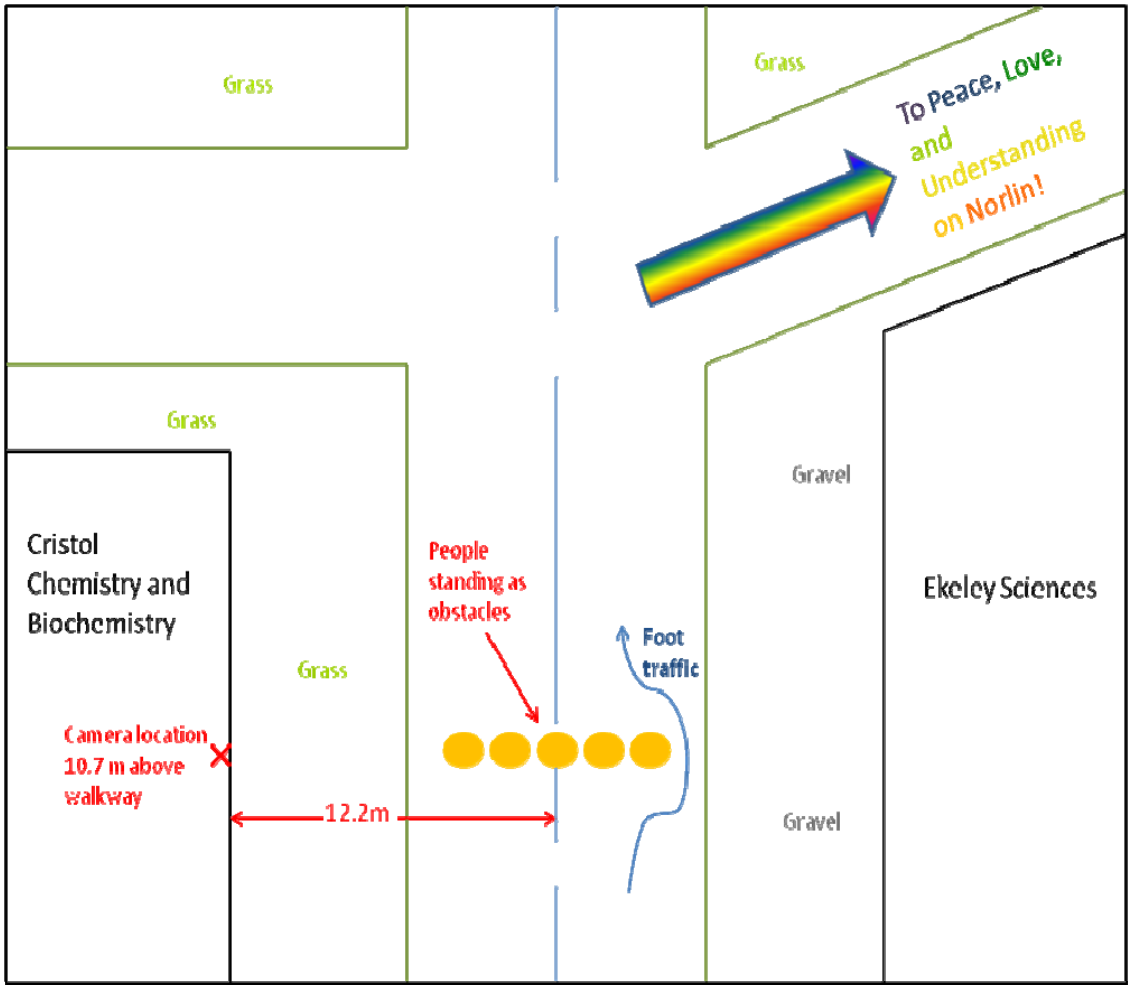

Figure 1: Diagram of the flow apparatus

3. Visualization Technique and Flow Description

3a. Calculation for Reynolds Number

A helpful assumption that can be made is that the ambient outside air temperature was a stoic 16 degrees centigrade. The average walking speed of a person is roughly 1.67 m/s [1]. Air density in Boulder (1,526 m above sea level) is 84.33kPa [2]. Air density and viscosity of air are both calculated based upon the difference in air pressure for Boulder, CO. The Reynolds number for the day is 120,000. For external flows, the Reynolds number indicates smooth laminar flow between the people and our static objects. Refer to Figure 2 for further information and assumptions.

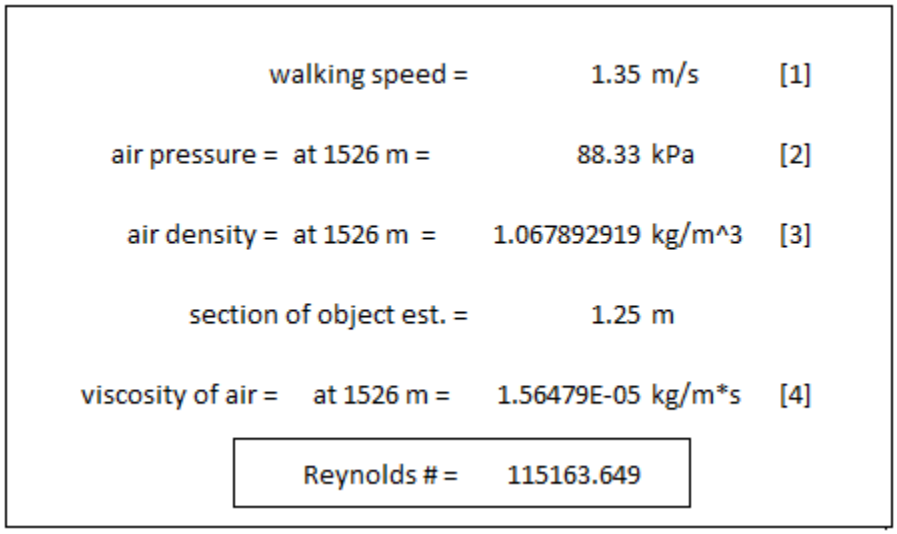

Figure 2: Reynolds number calculations

3b. Physics Analysis

The crowd of people walking along the walkway cannot be generalized into one method of traffic flow. Many subjects followed common driving laws and walked to the right but many walked along the path of least resistance. Many of the larger crowds simply bottled down while some of the crowds spewed off the walkway. A large crowd moves with many of the attributes of a fluid. However, unlike fluids, "…a crowd has the ability to think" [5]. A classical thought of crowds are that they "…are irrational, erratic and thus unpredictable, but a modern sociological view states that unorchestrated crowds are rational and can be expected to abide by scientific rules of behavior" [6].

The study of crowd flow is widely documented but is often inconclusive. Nevertheless, one ideal must be kept in mind, "A group of pedestrians is often composed of many pedestrian types with different walking characteristics and various objectives. If we consider a single type of pedestrian who is walking up a slope, this pedestrian may have a different characteristic stride from those walking down the same slope" [7]. There are some "hard" facts about crowds. The people in the crowd tend to follow the exaggerations of fluid flow. For instance, many people increased their speed when going through the confined space, and later decreased their speed so their friends could catch up. A visible boundary on a walkway is often seen as a flow enhancer. The video shows that many followed the walkway boundary on the north side (the rocks) but

many decided that the boundary was minuscule enough that it could be avoided (they walked on the rocks). A far fewer amount of people walked on the grass along the southern walkway boundary. When the subjects did walk on the grass it was only when walking east which seems to support the claim that they follow common driving laws.

4. Photographic Technique

Figure 3: Stereoscopic Image setup using simple slide bar. [8]

With the help of Professor John Hart, who specializes in stereoscopic photography, group Phi was able to use two cameras to produce a 3-D image. The cameras took one image each every second for forty minutes, totaling 4800 photographs with dimensions of 2048 x 1536 pixels. To produce 3-D photographs, the camera lenses must be set a specific distance apart depending on the distance from the cameras to the object. The "rule of 30" states that the camera lenses should be set 1/30 the distance to the object, or 0.539 meters for this apparatus. The cameras were connected to a laptop computer that synchronized their exposures. These synchronized images were then made anaglyphs and superimposed in Stereoscopic Player [9] to generate the final 3-D

images. The field of view is approximately 20 meters by 40 meters while the channel (walkway) is approximately 5 meters in width. It was a sunny afternoon so no extra lighting or flash was needed. The exposure settings were 1/500 second shutter speed and f/5.6 aperture value. The focal length was 5.8 mm. Figure 4 has been provided below displaying Adobe Photoshop's Exif data for a single photo.

Figure 4: Exif data for a single photo.

Make:	Canon
Model:	PowerShot A 590 IS
Date Time:	4/20/09 3:30-4:10 PM
Shutter Speed:	1/500 sec
Exposure Program:	
F-Stop:	f/5.6
Aperture Value:	f/5.6
Max Aperture Value:	f/2.5
ISO Speed Ratings:	80
Focal Length:	5.8mm
Lens:	
Flash :	Did not fire
	No Strobe return detection (0)
	Compulsory flash mode (0)
	Flash function present
	No red-eye reduction
Metering Mode:	Pattern

5. Revelations

The study of fluid mechanics can be applied to an aspect of study. The people used in this analysis behaved like fluids would in an internal flow. For larger densities of people, they increased speed and made a single file through our blockade, and decreased speed afterwards so their friends can catch up. We also noticed that flow happened in the direction of traffic. Which also leads to the fact that behavioral science can play a larger role in the analysis of human flows.

6. References

[1] Ralston, H. J. ‘‘Energetics of Human Walking,’’ in: *Neural Control of Locomotion*, R. M. Herman et al., eds., Plenum Press, New York 1976, pp. 77–98.

[2] “density of air.” www.google.com. 27 Apr. 2009 <http://en.wikipedia.org/wiki/Density_of_air>

[3] “air pressure elevation.” www.google.com. 27 Apr. 2009 <http://www.engineeringtoolbox.com/air-altitude-pressure-d_462.html>

[4] “dynamic viscosity of air.” www.google.com. 27 Apr. 2009. <http://www.engsolcom.com/Database_Pages/Data_PDF_Files/Visosity_at_High_Pressure/Dynamic_Viscosity_of_Air.pdf>

[5] Hughes, Roger L., “Flow of Human Crowds.” Jan. 2003. University of Melbourne, Australia. 28 Apr. 2009. <http://arjournals.annualreviews.org/doi/abs/10.1146/annurev.fluid.35.101101.161136>

[6] McPhail C. The Myth of the Madding Crowd.” New York: Walter de Gruyter, 1991. Pp 265

[7] Hughes, Roger L., “Flow of Human Crowds.” Jan. 2003. University of Melbourne, Australia. 28 Apr. 2009. <http://arjournals.annualreviews.org/doi/abs/10.1146/annurev.fluid.35.101101.161136>

[8] Hart, John. “Using a slide bar for stereo photography.” 2003. University of Colorado at Boulder. 27 Apr. 2009. < http://www.stereo3dgallery.com/SlideBar.shtm>

[9]Wimmer, Peter. “Stereoscopic Player.” 2009.www.3dtv.at. 23 Apr. 2009. <www.3dtv.at>

7. Original image before Adobe Photoshop