ANALYZING SHOE PRINTS IN FORENSIC SCIENCE

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ABSTRACT

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Forensic science uses many forms of technology in order to solve the missing pieces of the puzzle of a crime. One technique used is shoe print recognition. Shoe print recognition is one of the few methods that has been used for decades. Although the prints were not analyzed with all the technology used today, they were still a very crucial piece of evidence. Today, forensic scientists can use image processing to discover many beneficial clues, such as the shoe size, the shoe brand, a basic height of the person, and the events that occurred during the crime. In this experiment, several shoe prints will be obtained and analyzed using image processing to portray the factors of a shoe print. From the results of a study such as this, many criminals have been revealed and brought to justice.

1. INTRODUCTION

Forensic Scientists are constantly searching for new techniques to assist in solving crimes. Various methods have been used to catch the perpetrators. Shoe print recognition is no exception. Because nobody can fly, shoe prints are found more often than fingerprints because of their difficulty to be concealed. A study in several jurisdictions in Switzerland(Chazal, Flynn and Reilly)2 revealed that 35% of crime scenes have shoe prints that are used to solve the crimes. A shoe sole picks up various materials as they are worn, which creates a unique impression. Once a shoe print has been detected, investigators are able to analyze the shoe print to discover details that can identify many criminal and determine the events that occurred during the crime. This study will attempt to show that a photographed shoe print can reveal many important pieces of evidence like the shoe size, the brand of the shoe, and a basic height of the owner of the shoe when an image processing techniques are used.

2. BACKGROUND

Unknown to many people, a shoe print is almost as unique as a fingerprint. Every person treads a different path and has their own style of walking. As a result, every pair of shoes develops their own scratches, tears, and moldings. Those with a limp or lean to one side can be easily shown in a shoe print. These individual characteristics have greatly aided in catching many criminals.

Forensic scientists classify shoe prints into three different categories: patent, plastic, and latent. Patent shoe prints are clearly visible and are found in substances such as paint, dirt, or blood. Plastic shoe prints are found in soft, three-dimensional substances such as snow or mud. Lastly, latent prints are those that are not visible to the naked eye and are found on hard surfaces such as glass or concrete. Investigators can use various techniques to obtain these shoe prints.

They begin by taking a photograph, then use methods such as dusting with powders, electrostatic lifting, light oil, and plaster casts to preserve the print. In dry conditions, electrostatic lifting is used. In wet conditions, investigators use oil, casts, or spray. Then, forensic scientists are able to use image processing to analyze the shoe print for a profile and unique characteristics. Forensic and computer scientists such as Dr. Sargur Srihari(Singel) have been trying to construct a shoe database much like a fingerprint database for many years, with each criminal's shoes put into the system. However, because shoes can be replaced and they wear down, it is quite difficult to complete such a task. They have, however, been able to create a database of all shoes that have been manufactured, such as SoulMate, TreadMark, and many others. When a shoe print is recovered, it is run through the database to see what the brand is. From these processes, many criminals have been positively identified.

3. METHODS

To begin the experiment, several volunteers made a shoe print in three different locations: on floor tiles, on a piece of paper, and on concrete outside. The shoe print on a piece of paper was easier to analyze because of its smoother, brighter surface. Out of the three kinds of shoe prints, plastic prints were used because of their clear prints. Mud was preferred because dirt was not available in large quantities and clumps, so it scattered very quickly and did not maintain a print, and snow was not available. The testers placed their right foot in a tray of mud, and then pressed their foot onto the object of each location. After the shoe print was made, several pictures were taken from various views. The first picture was of the entire shoe print to get the size, position, and location; using a piece of paper as a scale as seen in Figure 3.1.

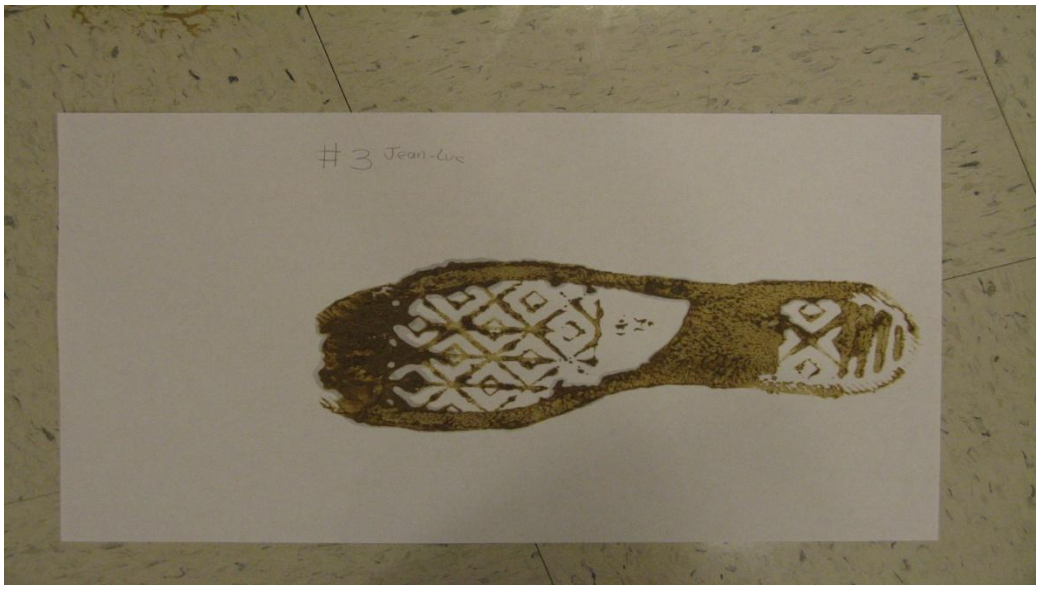

Figure 3.1- Picture to determine size of shoe

Then, several close-up pictures were taken to increase the resolution: some of the front of the shoe as shown in Figure 3.2, where the most patterns occur, and one of the back.

Figure 3.2- A close picture of a shoe print

Lastly, a picture of the actual shoe sole was taken. The actual shoe dimensions, the height, and the shoe brand was then obtained from each participant and recorded in Excel as a reference for the estimated information determined by image processing. (Table 3.1)

Table 3.1- Actual Measurements

Name	Shoe Size	Shoe Size (Inches)	Height (Inches)	Brand
Alex Chin	10	11.5	66.5	Avia
Amy Kalinowski	7	10	67.5	Rainbow
Jean-Luc Rivera	12	12.5	71.5	Converse
Greg Taylor	11	12	73.5	Converse
Ethan Sherbondy	10.5	12.5	72	Asics
William Greene	9	12	72.1	Adidas
Brynn Claypoole	7.5	10.5	65	Rainbow
Maria Lucas	7	10	64	Rainbow
Manoj Mirchandani	13	13.5	63.5	Nike
Hailey Little	11	11.25	71	Reef
Josh Hodges	10.5	12.5	70.75	Sketchers
Meg Everist	8	10.5	64	American Eagle
Hall Liu	9	12	69	Nike

Once all shoe prints were recorded, the pictures were uploaded onto Image J. Image J was chosen as the image enhancer because of its ability to remove noise and efficiently sharpen images. The prints were then processed by removing any outside distractions such as excess dirt, spots, or smudges. By using the image as in Figure 3.1, the shoe size was determined by setting the scale of the piece of paper that the shoe print was on to 17", then measuring the shoe print from the tip of the outsole to the bottom. A vertically straight line was drawn to two of the outer points of the shoe, and then the line to measure was drawn perpendicular to the vertical line as seen in Figure 3.3. This was done to ensure that each shoe was measured the same way.

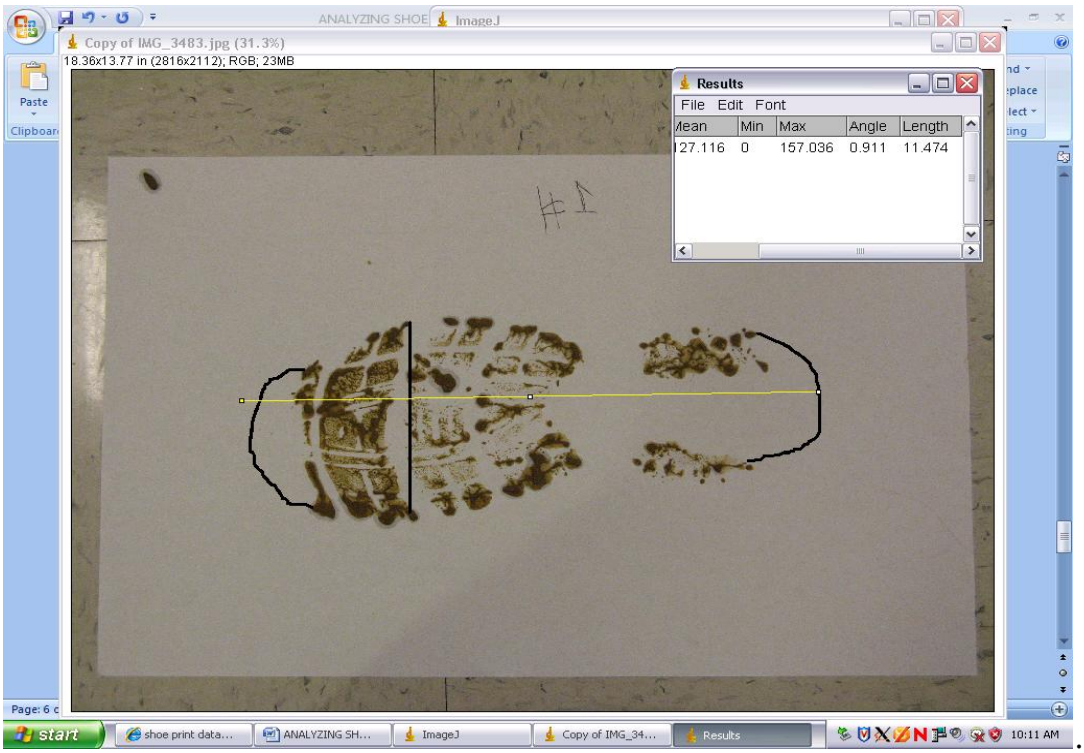

Figure 3.3-Measuring the shoe size

Many of the prints were not the entire shoe sole, which is similar to a real investigation, as criminals would not intentionally leave a footprint. Therefore, knowing the shoe's brand is very helpful. Each type of shoe has a unique pattern on the bottom; making it easily identifiable. Tennis shoes have a distinct pattern at the top of the shoe sole, whereas flip flops have the same pattern on the entire bottom of the shoe, which eventually fade into a smooth sole. A flip-flop or sandal shoe print will also leave an entire shoe print as shown in Figure 3.4, but a tennis shoe will only leave a print of the top and bottom shoe sole, not the middle. For example, the shoe print in Figure 3.2 is from a Converse. By examining the prints on the Converse websites, it is shown that all Converse shoes have a diamond within a diamond pattern. From this characteristic, the shoe print was able to be compared to Converse shoes to fill in the missing spaces. Also, Converse manufactures their shoe sizes differently than other popular brands. In

real-life cases, investigators purchase the same shoe as the print and compare the two. In this study, the shoe print was compared with the picture of the bottom of the shoe that was taken.

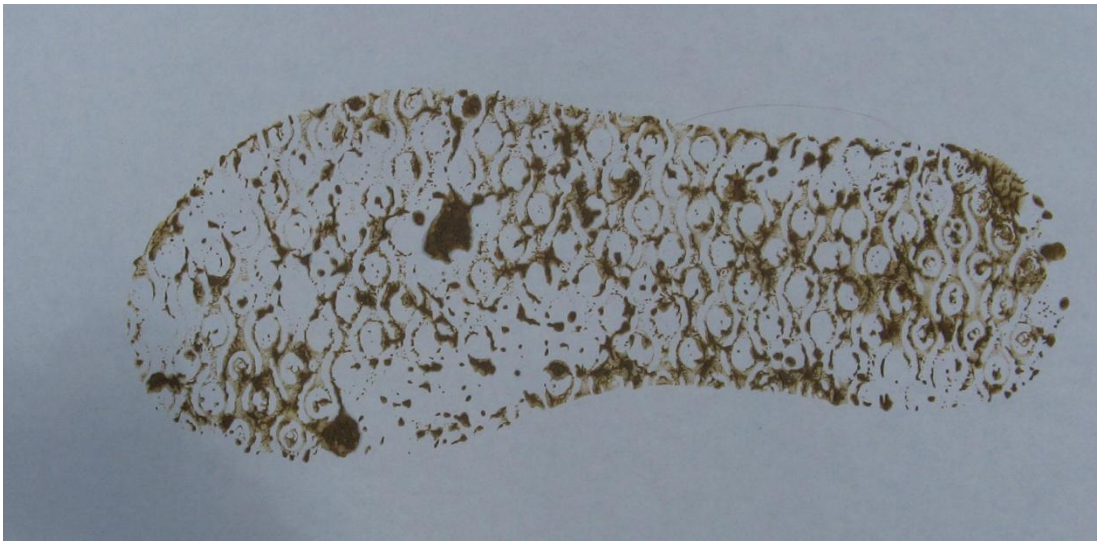

Figure 3.4-Flip Flop-the shoe is flat on the paper

After determining the shoe sizes, a basic height of the person could be estimated based on an average correlation between shoe sizes and height. The length of a person's forearm equals the length of their foot from the heel to the end of the big toe. Therefore, the bigger the shoe print usually means a taller person, but this is not always the case, so forensic scientists can only make a broad estimate.

Lastly, the brand was determined by looking at the patterns or labels on the shoe. As mentioned above, each brand has a unique pattern, such as Converse or Nike. Databases would be available for investigators that would quickly find the brand of the shoe; however this study did not have access to such. Therefore, the pictures taken originally of the shoe sole were used to compare to the shoe prints so as to match the correct brand as seen in Figure 3.5.

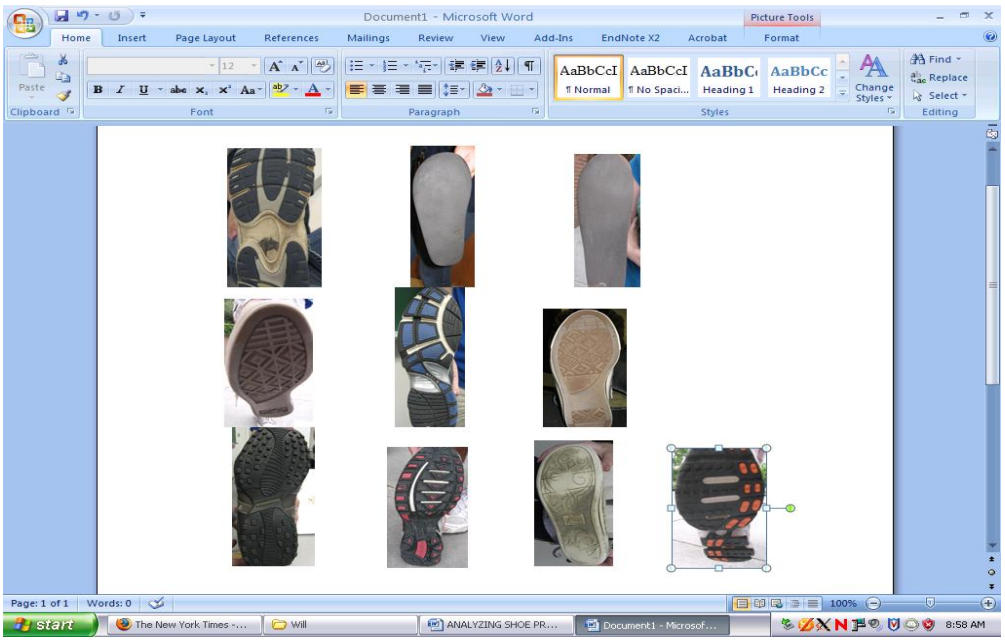

Figure 3.5- Shoe Print Database

4. RESULTS

Table 4- Shoe Sizes using Image J

Name	Shoe Size (Inches)	Shoe Size	Height (Inches)
Alex Chin	10	11.474	66.5
Amy Kalinowski	6.5-7	9.226	67.5
Jean-Luc Rivera	11.5-12	12.482	71.5
Greg Taylor	11-11.5	12.289	73.5
Ethan Sherbondy	10.5-11	12.239	72
William Greene	10-11	12.186	72.1
Brynn Claypoole	7.5-8	10.56	65
Maria Lucas	7-7.5	9.899	64
Manoj Mirchandani	12-13.5	13.46	63.5
Hailey Little	10-11	11.351	71
Josh Hodges	10.5-11.5	12.472	70.75
Meg Everist	8-8.5	10.499	64
Hall Liu	9.5-11	12.003	69

5. CONCLUSIONS

By analyzing the shoe prints, a very close number of shoe sizes in inches and the correct shoe brand were obtained. However, only a shoe size range could be found because each manufacturer's shoes fit differently. By comparing several shoes such as Converse and Adidas, it was easy to see the difference in size; even if the the size number was the same. Forensic labs have detailed shoe databases that compare the shoe sizes to allow the scientists to learn the actual shoe size of a print. It was also difficult to estimate a height because there is only slight correlation between shoe size and height. It was determined that the correlation is .382105, as opposed to one, which is a positive correlation One tester had a shoe size of 13 in men's (Table 3), but only had a height of 5'3"; yet another tester had a shoe size of 9 in men's, but had a height of 6'1". This could be due to the age of the testers. They were all teenagers, which mean that many are still growing and there shoe size is not proportional to their body.

6. FUTURE WORK

Other studies can be completed on more difficult shoe prints, such as those with many smudges or pivotal marks. Technology has improved much over time, making it possible to obtain some evidence from the print, even if it is hardly any. A deeper study would be to test adults to see if they have a correlation between their height and shoe size. They have stopped growing, so a stronger correlation might be present. Another interesting study would be to analyze a latent print on glass or another object that makes a print invisible to the naked eye. Also, studies could be conducted to analyze the actual marks and tears as mentioned in the background. It can be determined that if by looking at the unique "wear and tear" of each shoe; it can be used to positively identify each shoe.

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