Fighting Crime with AI: Suspect Identification from Shoeprint Impressions

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Abstract

Shoeprints are one of the most common types of evidence left behind at crime scenes, which are just as important as fingerprints to find a suspect. The determination of an individual's gender through shoeprint impressions is a labor-intensive process demanding specialized expertise because of the specific patterns a shoeprint creates. This study aims to streamline and expedite the gender and shoe identification process by leveraging deep learning methodologies applied to a dataset, 2D Footwear Outsole Impressions, that contains 1,500 2D images of 150 pairs of shoes that were scanned 5 times per shoe. The adoption of a convolutional neural network (CNN) is central to this endeavor, exploiting its capacity to discern patterns within extensive datasets. Through a meticulous training regimen involving an 80/20 data split and validation via cross-validation techniques, the CNN is poised to outperform other traditional machine learning models for image classification. The intrinsic ability of CNNs to extract features and spatial patterns from images, positions them as the optimal choice for this research work. Anticipating accurate gender from 2D shoeprint images, this research aspires to enhance efficiency in forensic gender offering a notable advancement in both time and resource savings. In conclusion, the CNN models showed promising results in identifying patterns in the shoeprint images, demonstrating higher accuracy rates.

Background Information

Shoeprints are created when the sole of a shoe meets a surface such as dirt, snow, or any other surface that can retain an impression. These impressions provide vital information in crime scene investigations, offering insights to the actions of a suspect at the scene. Shoeprints can vary based on the tread's appearance depending on design of the shoe's sole, the gender of the suspect, the age of the suspect, and the shoe size. By comparing impressions left at crime scenes with known footwear examples, forensic experts can link suspects to crime scenes, aiding in successful prosecutions.

Dataset

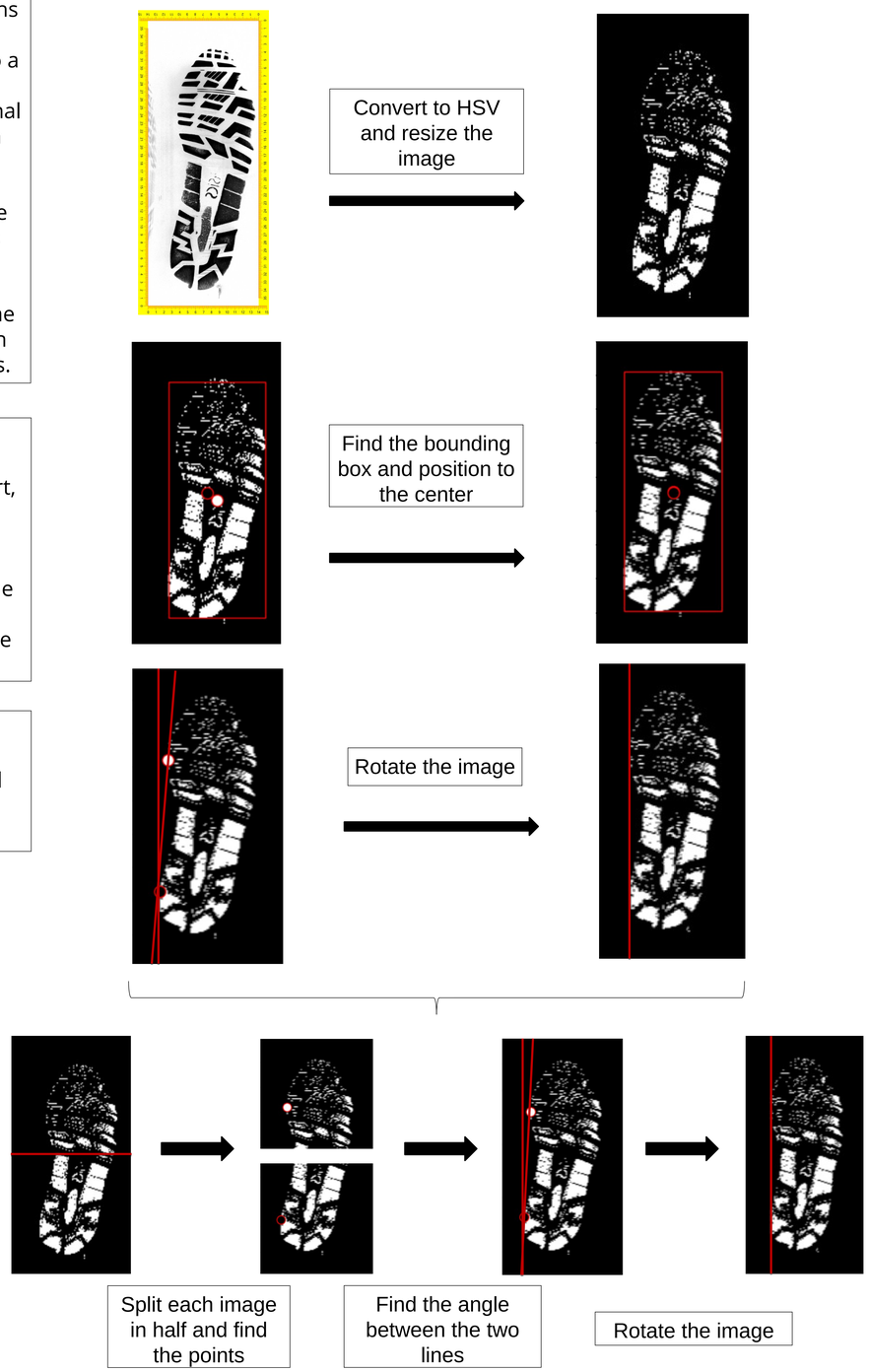
The dataset, 2D Footwear Outsole Impression, consists of two-dimensional images of shoeprint impressions. There are 1,500 impressions from 150 pairs of shoes that were scanned 5 times each.

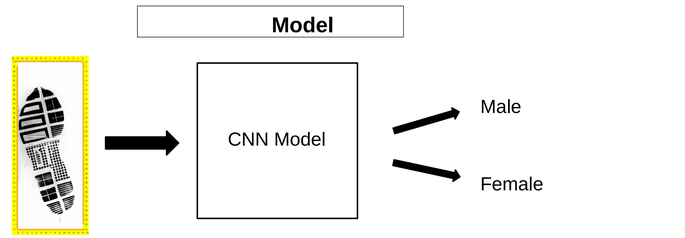
Figure 1

Figure 1 – Four examples of the original images from the dataset.

Data preprocessing

A vital part of this project was data preprocessing to optimize deep learning model performance. Utilizing HSV conversion, image positioning, and image rotation enhanced model accuracy significantly.





Model Performance

Model Name	Preprocessing	Accuracy	Precision	Recall
AlexNet	Raw	45.89%	96.97%	19.04%
AlexNet	HSV	83.33%	87.82%	81.55%
AlexNet	Positioned and Rotated	82.67%	94.62%	73.21%
VGG16	Raw	51.94%	54.14%	100%
VGG16	HSV	56%	56%	100%
VGG16	Positioned and Rotated			
ResNet50	Raw	97%	90.16%	98.21%
ResNet50	HSV	94.67%	92.22%	98.81%
ResNet50	Positioned and Rotated	56%	56%	100%

Figure 5

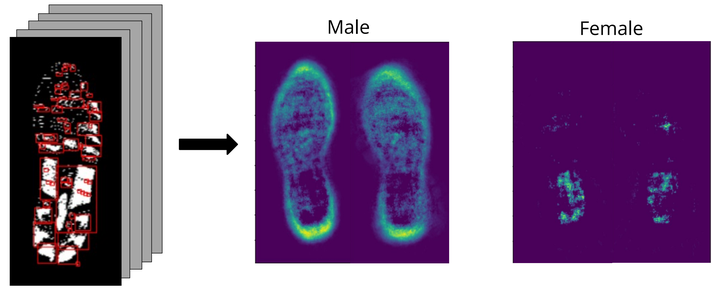


Figure 5 – Only the contours with a bigger area were recorded, mapped together, and averaged, which created images of pressure points for each gender (a).

Conclusions:

In conclusion, our efforts to preprocess the images proved to be beneficial in enhancing the accuracy scores from each model. However, we encountered challenges specifically related to the positioning and rotation of the data, which we plan to further investigate in the future. We believe that solving those challenges will improve the performance for all models that use the positioning and rotation data.

Future Directions:

Moving forward, our goal is to develop our own gender classification model, aiming for better performance compared to existing models. Additionally, we intend to create models dedicated to shoe brand identification.

References:

M. Hassan, Y. Wang, D. Wang, D. Li, Y. Liang, Y. Zhou, D. Xu "Deep Learning Analysis and Age Prediction from Shoeprints," arXiv preprint arXiv:2011.03794, 2020

Park, Soyoung; Carriquiry, Alicia (2020). 2D Footwear outsole impressions. Iowa State University. Figure. https://doi.org/10.25380/iastate.11624073.v1