Effect of Weight on Outsole Impressions

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Project Rationale & Goals

- Previous research has shown that weight influenced bare footed impressions.
- Researchers have used linear regression with manually measured features to capture the weight effect on shoe prints.
- Our goal was to quantify the effect of weight on a shoe print using novel applications of collection methodology, computer vision, and deep learning algorithms.

Data Collection

Shoes:

- 8 pairs of men's gym shoes (size 9-11)
- 12 pairs of women's gym shoes (sizes 8.5-10)

Materials:

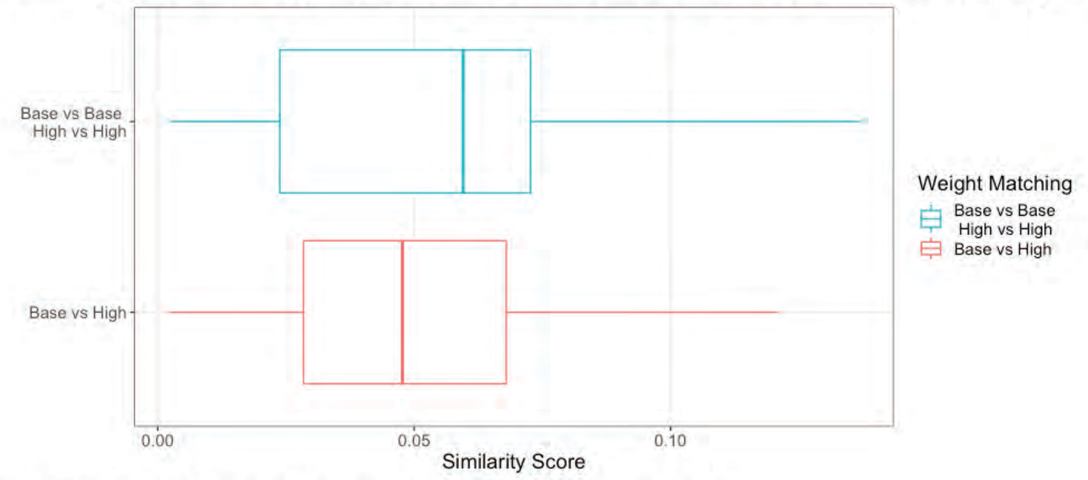
- BVDA inkless two-piece Sole Print
- Weighted vest with 6 lb weights (total 60 lbs)

Methodology:

- Replicate impressions were created using the 6-step stepping methodology established by Singh, B., Krishnan, K., Kaur, K., et al.
- The prints were scanned using an EPSON DS-6500 at 8"x16.5", 300 dpi, and 8-bit grayscale.
- We had 136 total images but used only 68 for preliminary analysis of 1 participant.

Methods

- Images were pre-processed to reduce noise and enhance image quality.
- Two weight levels: **base weight** (approx. 143 lbs) and **high weight** (approx. 205 lbs)
- **Exploratory**: Compared base and high weights
  - We used ResNet34 to identify 512 similarity features.
  - Are there differences between images of the same shoe when the wearer changes weight by 60lbs?
- **Global**: Compared same and different weights
  - We constructed pairs of images of a single shoe for same weight (base vs base, high vs high) and different weight (base vs high) scenarios.
  - Images in a pair were aligned using speeded up robust features (SURF) and iterative closest points (ICP).
  - A regression model was fitted to the average pixel intensity of the entire outsole across all participants and weights.
  - Phase-only correlation was used to calculate a similarity feature.



Impressions with the same weight (base vs base and high vs high) and different weights (base vs high) were compared using phase-only correlation, which produced a similarity score.

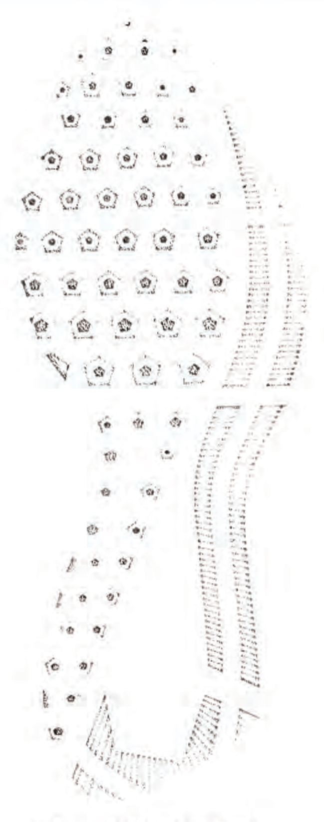
We detected promising but not significant differences in the similarity score of shoes of the same weight and shoes of differing weights.

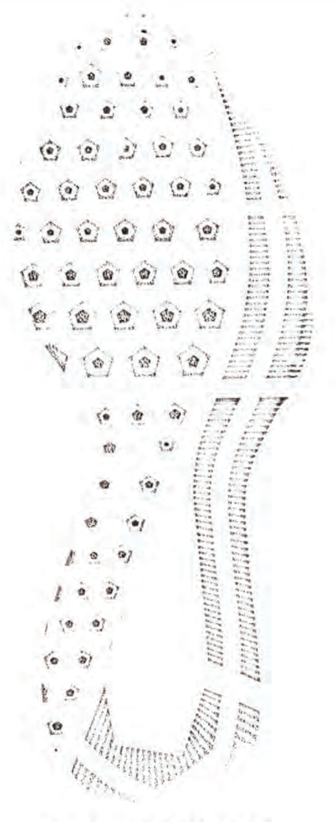
- **Local**: Compared within shoe, base vs high weights
  - We applied a grid segmentation in order to determine if there were areas of the outsole that were more affected by change in weight.

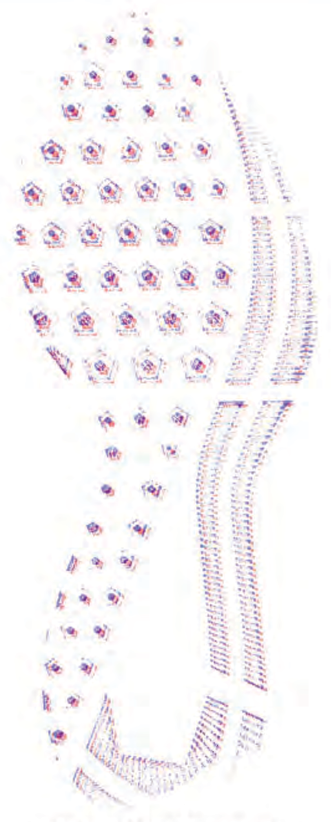
Results and Discussion

- Based on the aligned images, we observed promising differences on various parts of the shoe print, notably the **heel** and **ball** parts.
- The contact area detected by our edge detection algorithm increased by **about 5%** between shoe prints with body weight and maximum weight for Shoe01R-M2.
- Results from a linear regression model showed that, for every **6 lb increase, pixel darkness increases by 0.2 units** on average (significant at 90% confidence level).
- Overall, we found that a 60 lb weight difference **does** affect the shoe prints created. We couldn't find a significant difference using the phase-only correlation. This may affect examiners' ability to accurately identify shoe prints.
- Limitations:
  - Randomly acquired characteristics (RACs) caused data loss on the shoe impressions which interfered with the alignment algorithm.
  - Some of the data could not be used because different participants had varying pressure distributions.
  - By looking at the entire shoe print with the phase-only correlation, we wash out differences that may be more prominent in local areas.

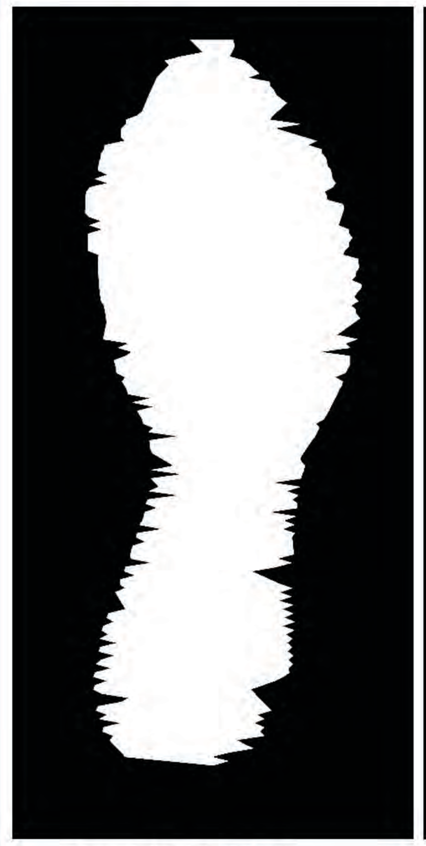
Alignment

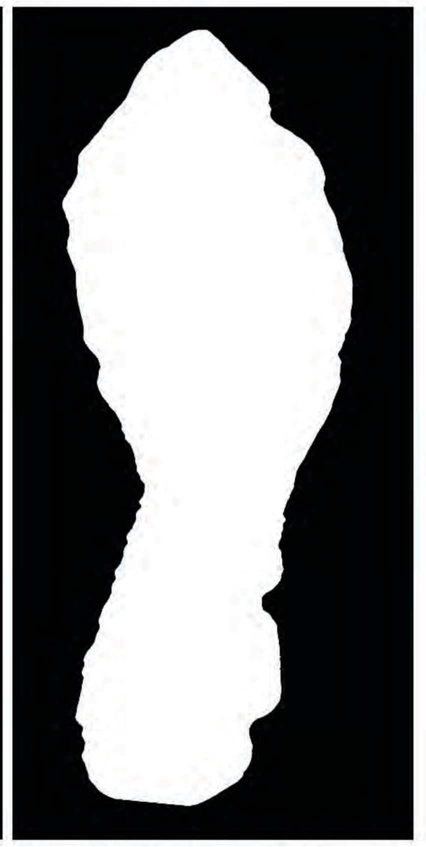

Shoe01R-150-M2


Shoe01R-211-M2


Shoe01R-Aligned

Edge Detection


Shoe01R-150-M2


Shoe01R-150-M2-Optimized

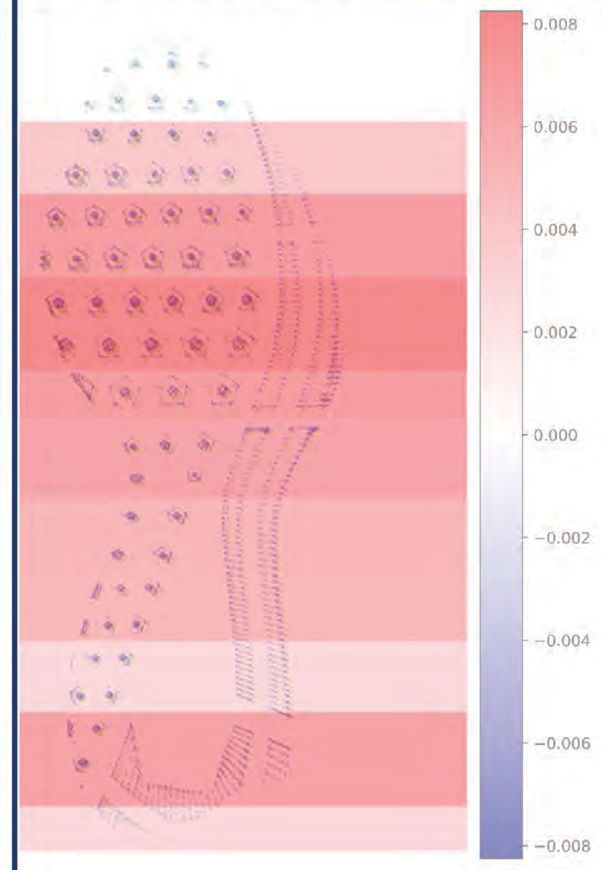
We detected the centroid of the shoeprint and divided the image into 2 halves.

For each half, we detected the first black pixel, coming from the side, and adaptively jumped to the next pixel of the next row.

All detected pixels were connected by lines.

We smoothed the rough edges with the Pillow Smoothing Image Filter.

Grid Segmentation of Pixel Intensity



Shoe01R at body weight and at maximum weight were overlaid and segmented into rows that interfered with regular patterning the least.

For each segment, we computed the proportional difference in the average intensity between the shoe prints with body weight and with maximum weight added.

The red indicates a higher proportional pixel intensity from Shoe01R at maximum weights. The blue would indicate the same but at body weight.

Next Steps

- Focus on interpretable features to quantify differences between outsole images at various weights.
- Identify the regions of the shoe where the most deformation occurs.

References

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