Footwear Evidence and Modelling Accidentals

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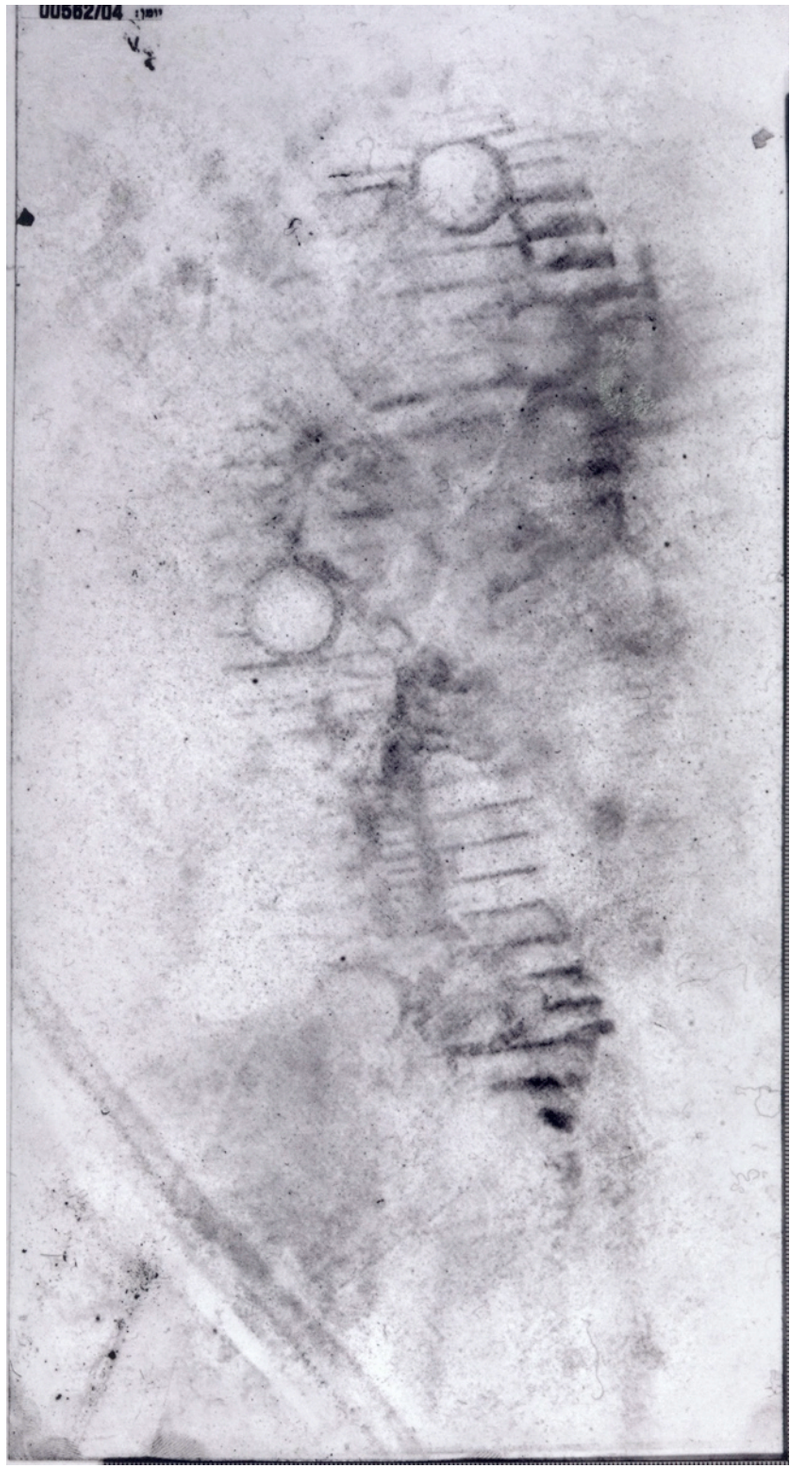
Motivation: Are these a match?



CRIME SCENE PRINT

SUSPECT'S SHOE

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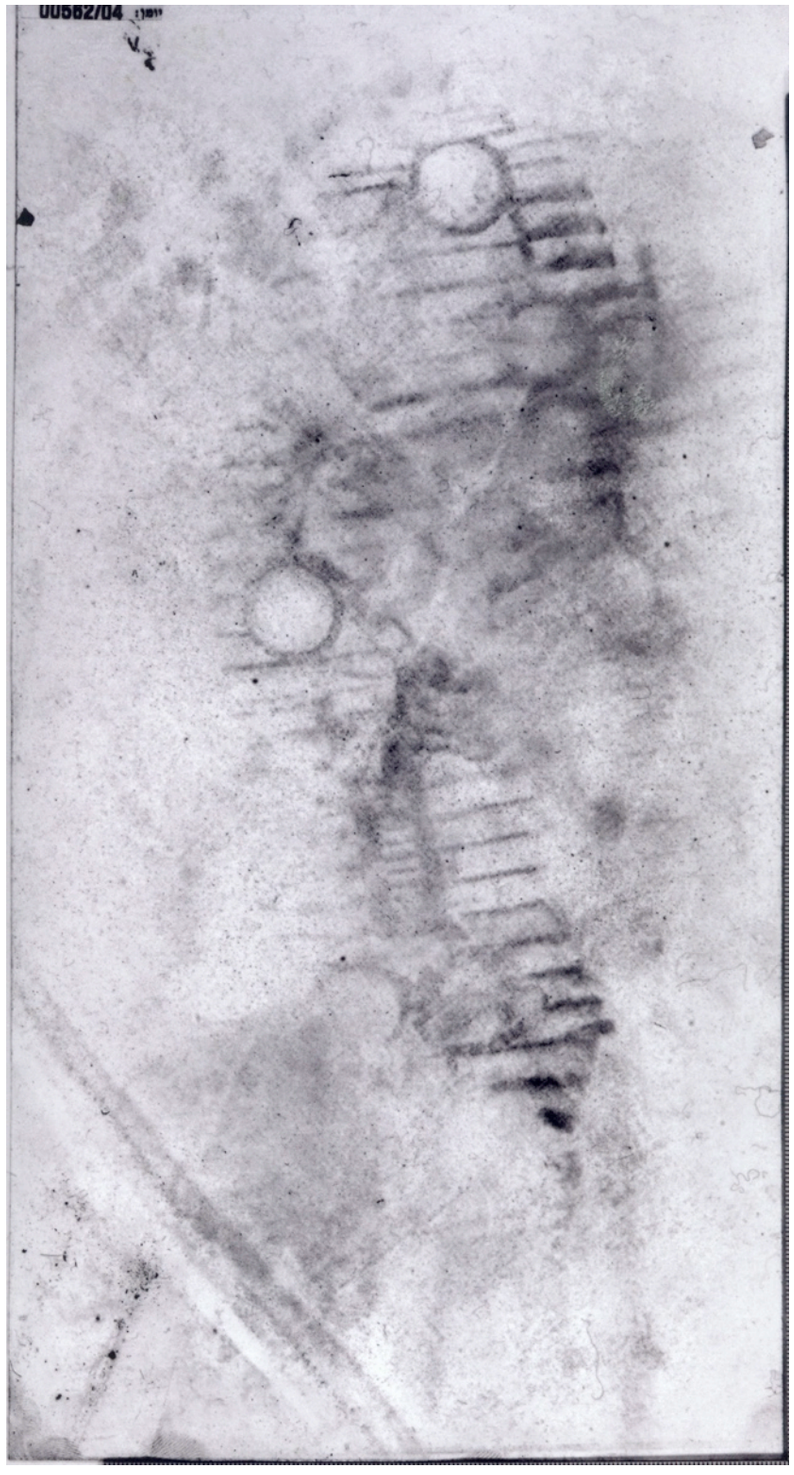

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Step 1

Class Characteristics

Brand, Type, and Size

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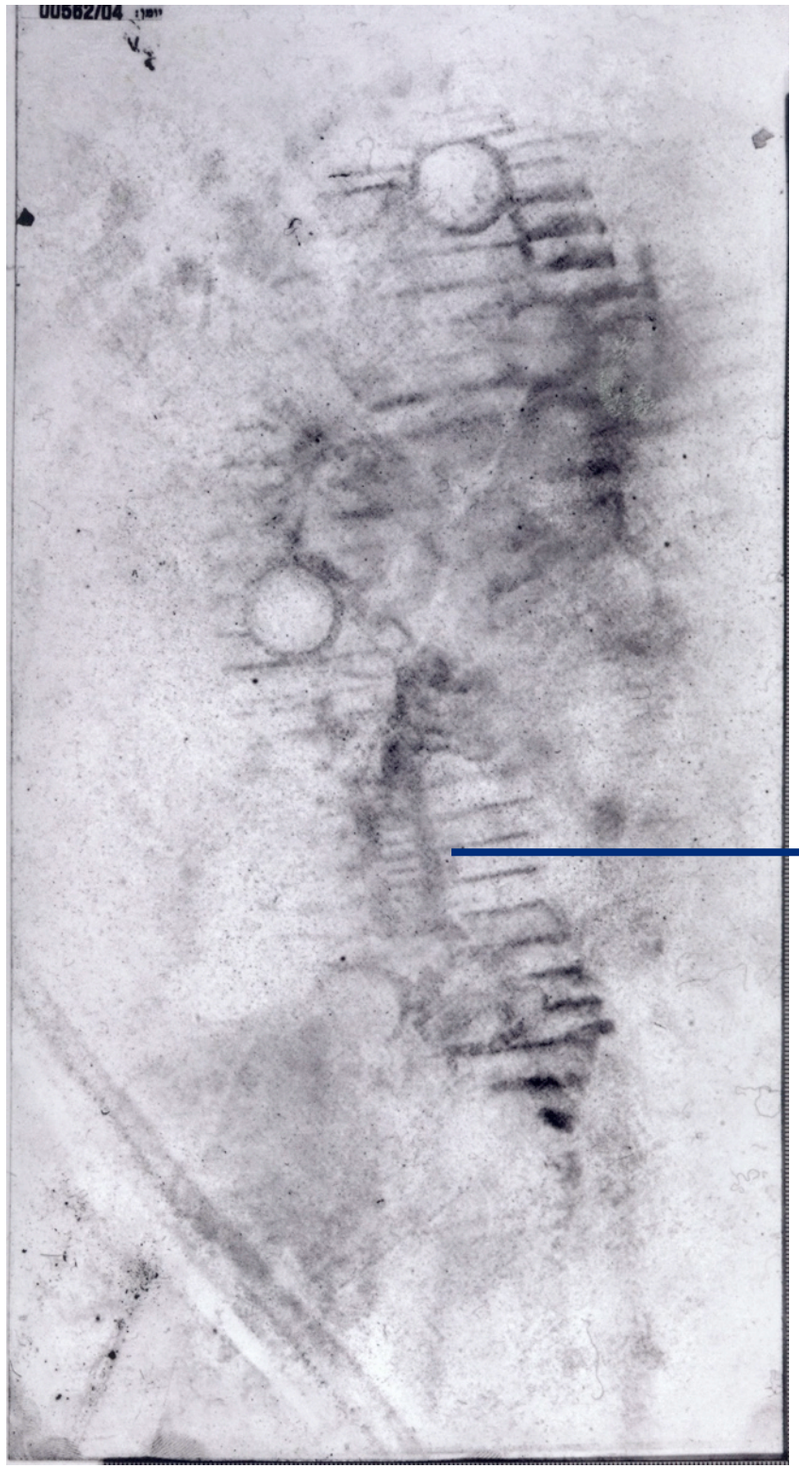

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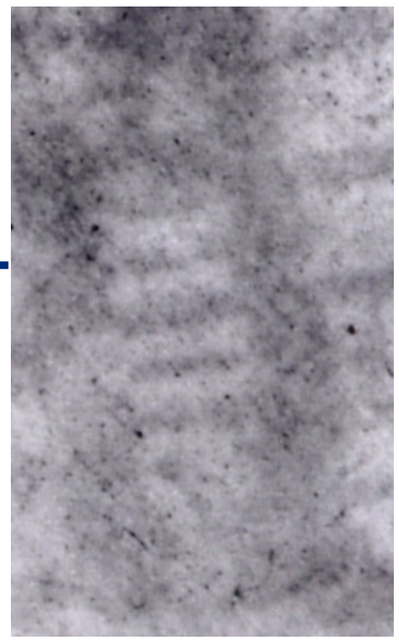

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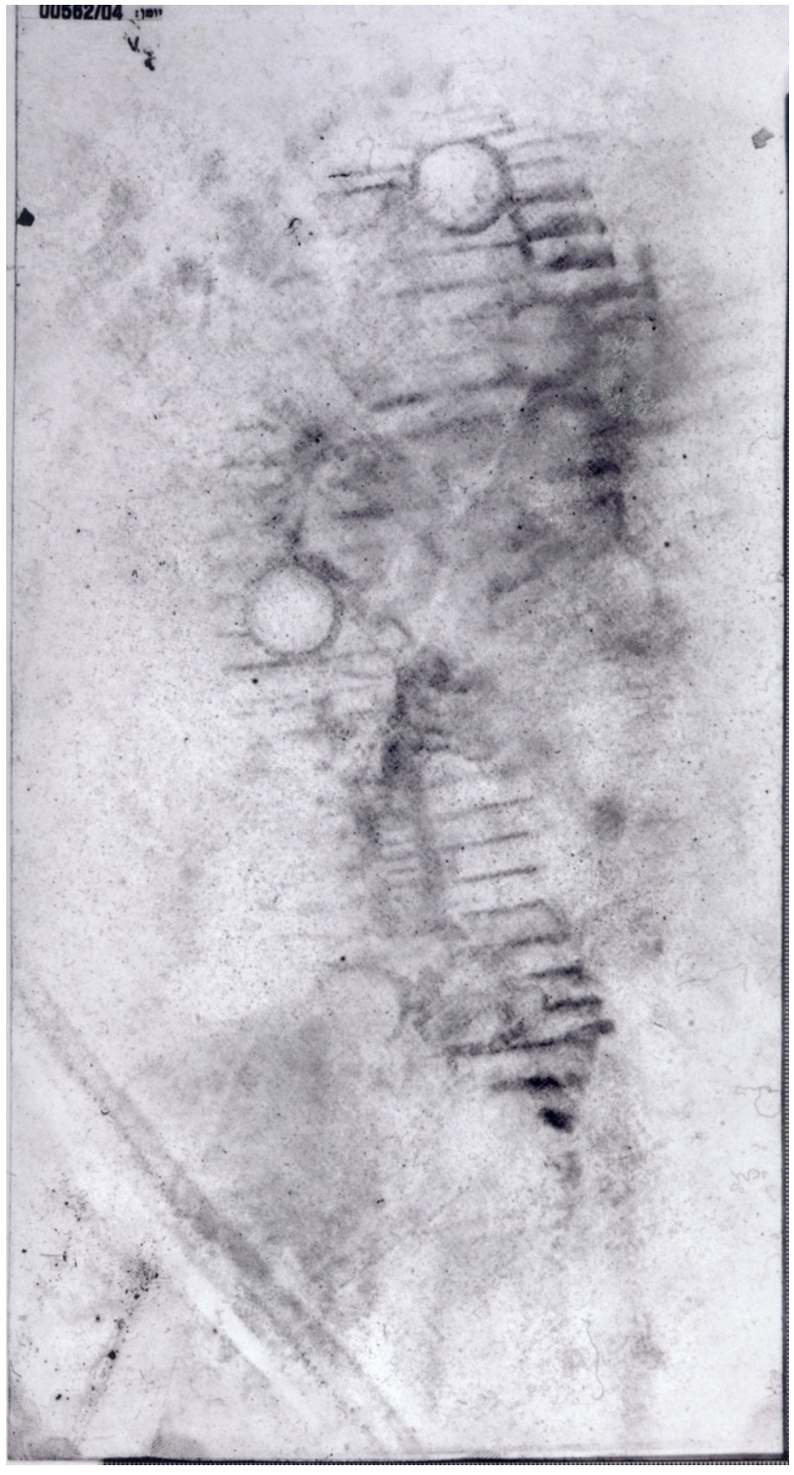

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Accidentals (RACS)

Holes, Cuts, Scrapes, etc.

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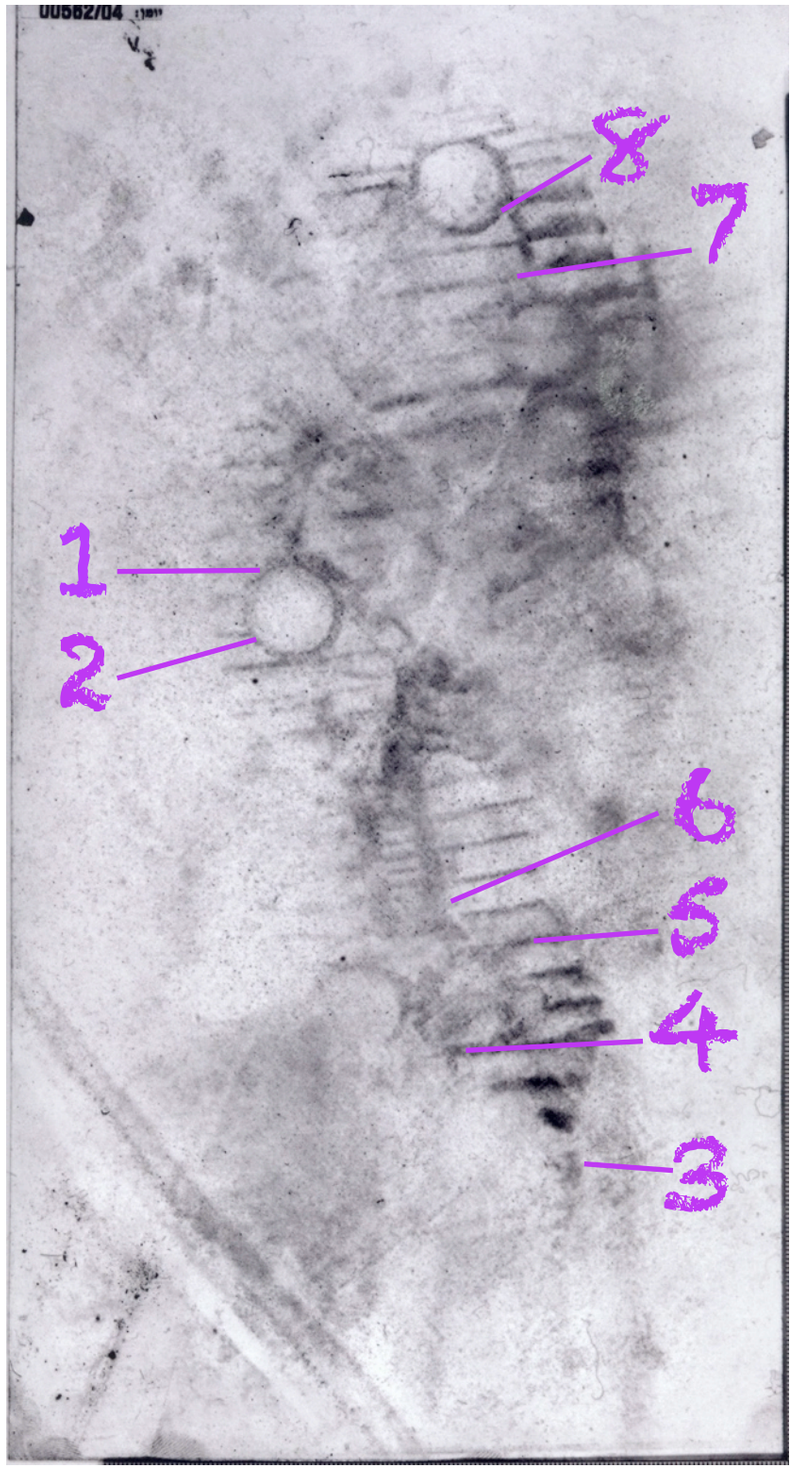

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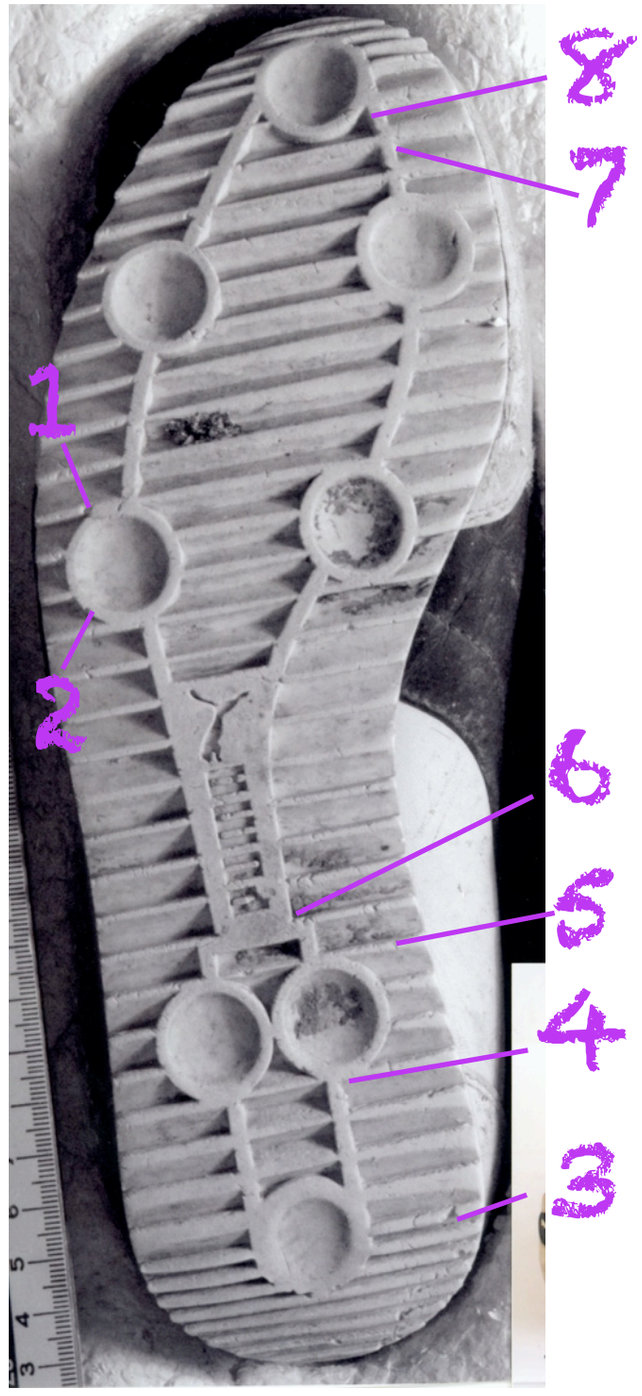


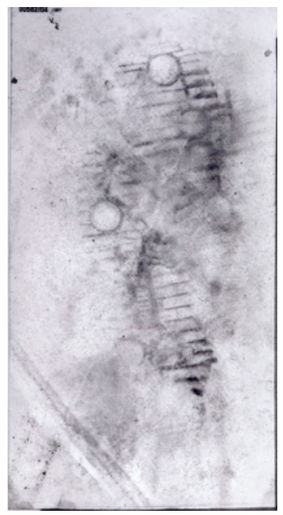
CRIME SCENE PRINT

SUSPECT'S SHOE

Similarity assessed by likelihood ratio

MATCH

$$P\left(\quad = \quad \right)$$



NO MATCH

$$P\left(\quad = \quad \neq \quad \right)$$

Similarity assessed by likelihood ratio

$$= \frac{P(\text{Suspect Shoe} \mid \text{RACs})}{\Sigma\, P(\text{Other Shoes} \mid \text{RACs})}$$

$$= \frac{P(\text{RACs} \mid \text{S.S.})P(\text{S.S.})}{\Sigma\, P(\text{RACs} \mid \text{O.S.})P(\text{O.S.})}$$

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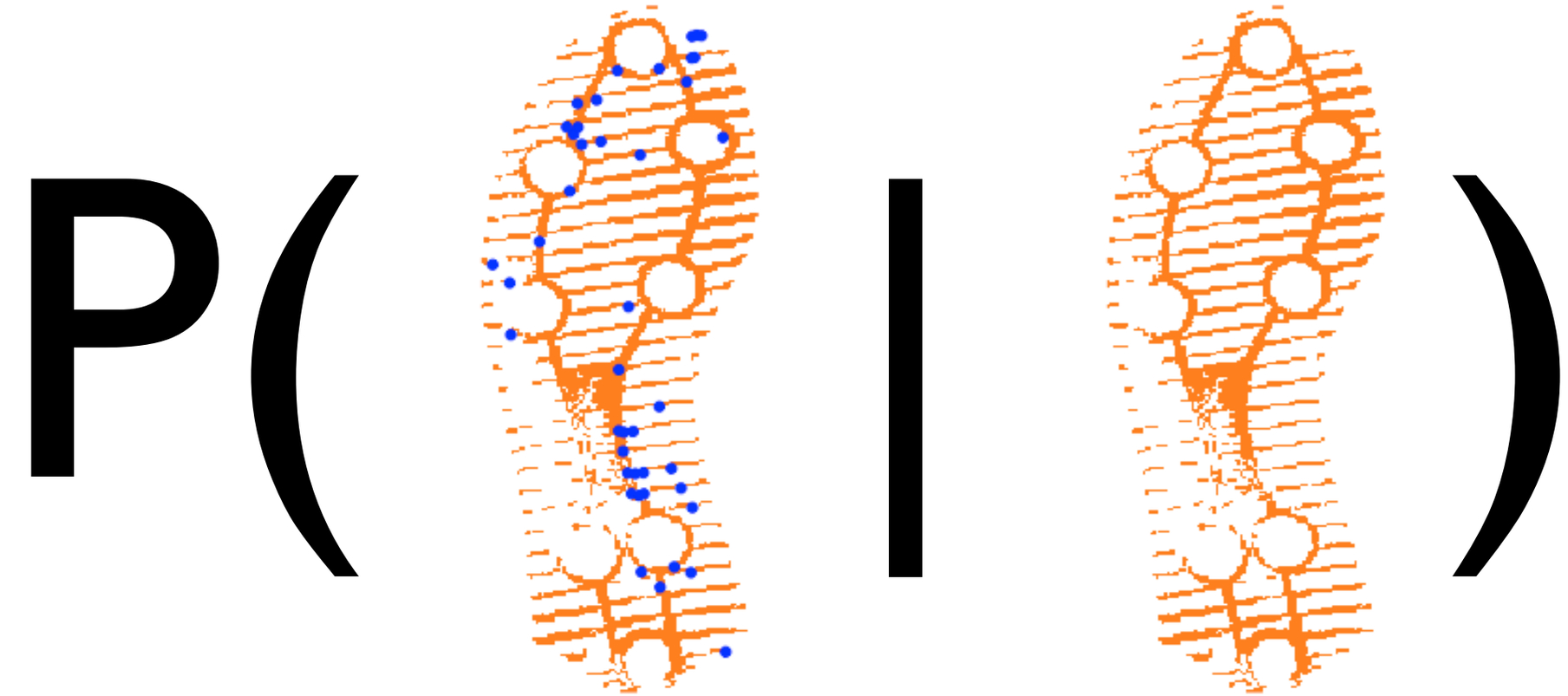
This is the focus of our work

We are developing a statistical model for

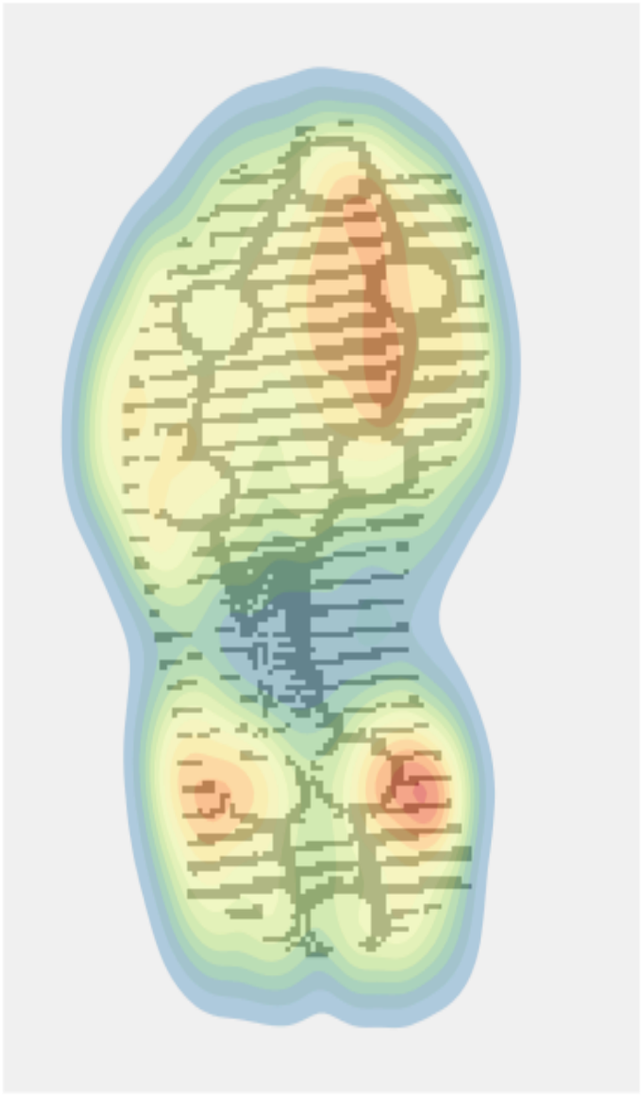


Probability of Accidentals given the Shoe

We are developing a statistical model for

Example

$P(\bullet \mid$  $) =$



Probability of Accidentals given the Shoe

The Existing Approach

Footwear Examinations: Mathematical Probabilities of Theoretical Individual Characteristics (Stone 2006)

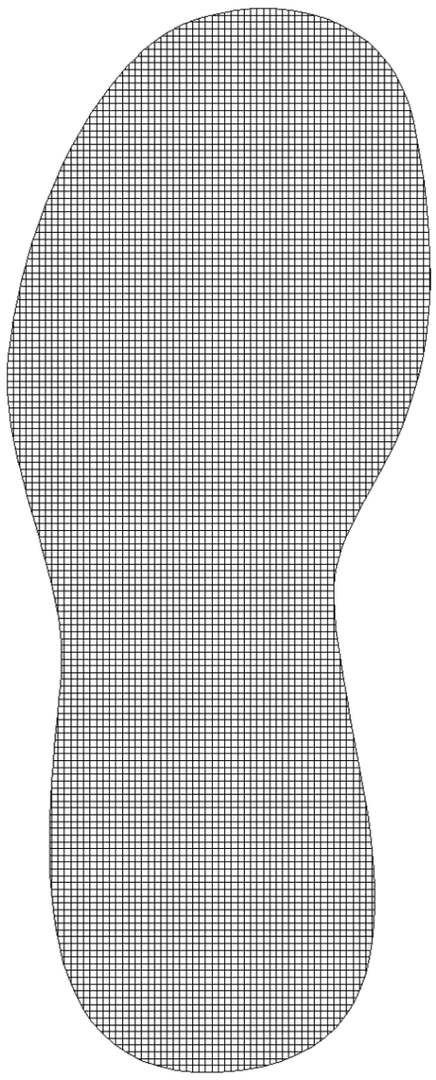


Figure 1

Hypothetical shoe with 16,000 sq mm grid.

Model Set-up

- Uniform density
- Independently distributed
- on hypothetical contact

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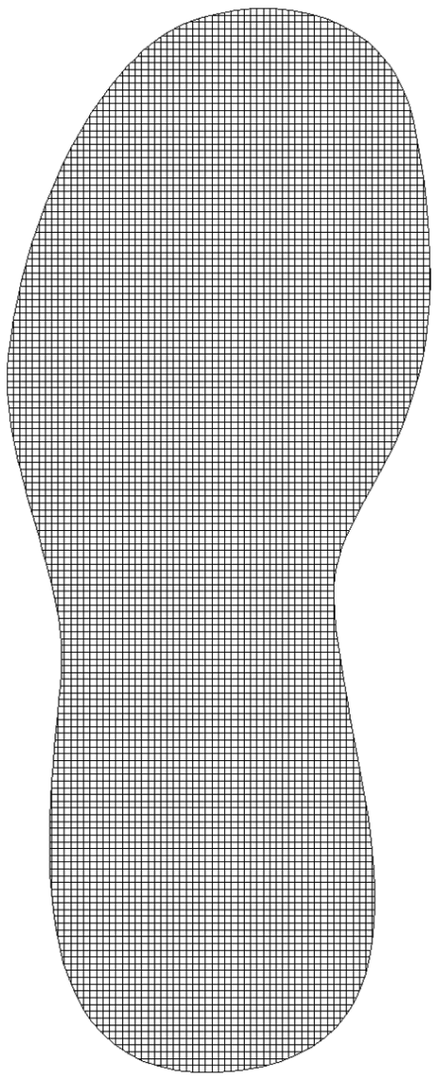


Figure 1

Hypothetical shoe with 16,000 sq mm grid.

Model Set-up

- Uniform density
- Independently distributed
- on hypothetical contact

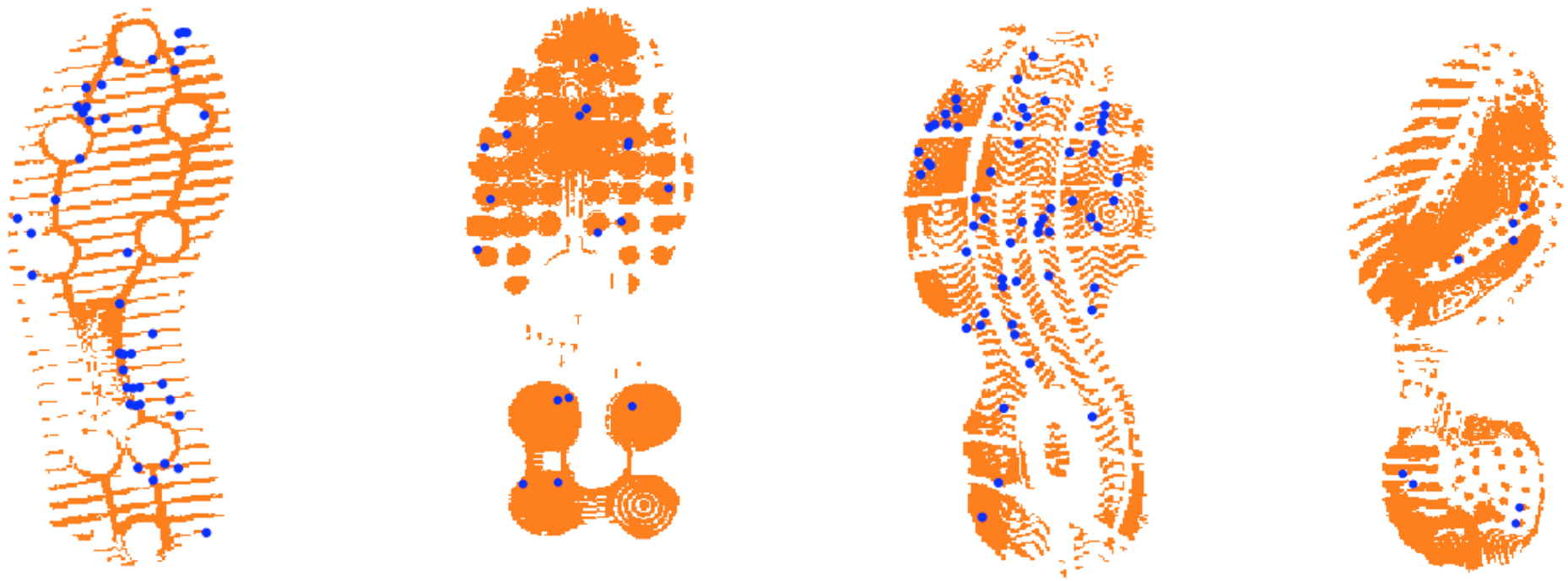
Drawbacks

- Not based on data
- No use of contact surface

Data

386 marked, aligned, and normalized impressions

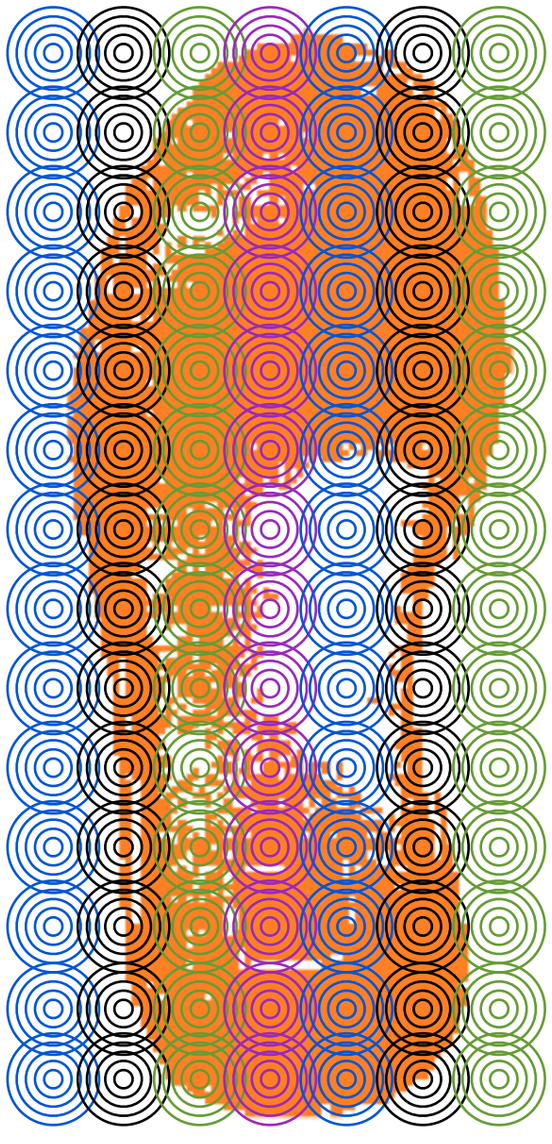
of men's shoes from real cases by the Israeli Police



Two parts: Accidentals and Contact Surface

Newly Proposed Model

$$f(x,y) = \sum_{i=1}^{k_1}\sum_{j=1}^{k_2} \pi_{ij} \mathrm{Beta}(x|i, k_1 - i)\mathrm{Beta}(y|j, k_2 - j)$$



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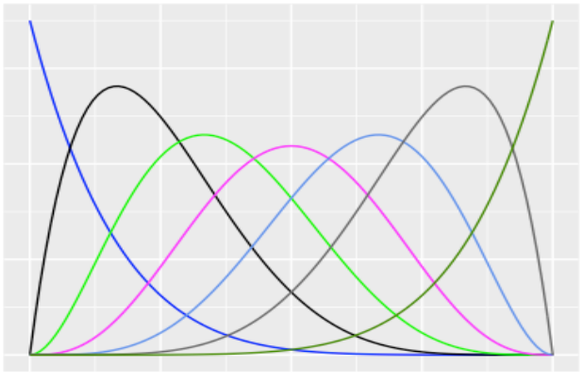

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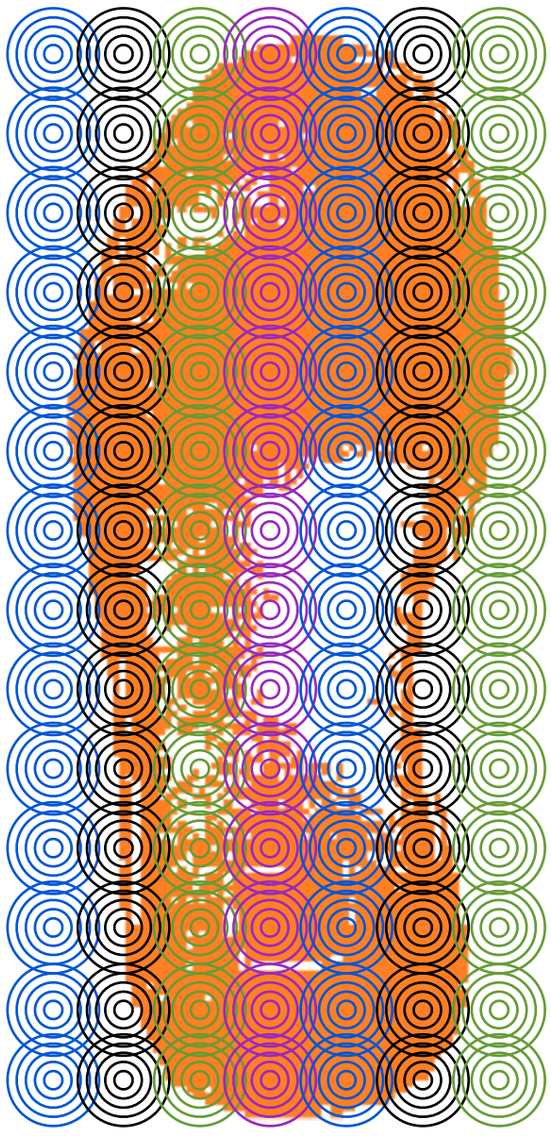
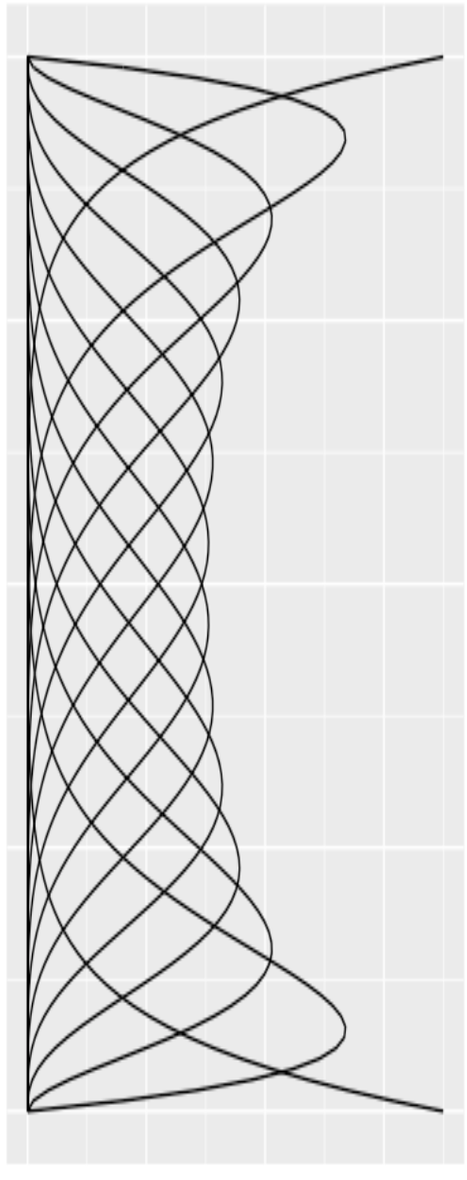


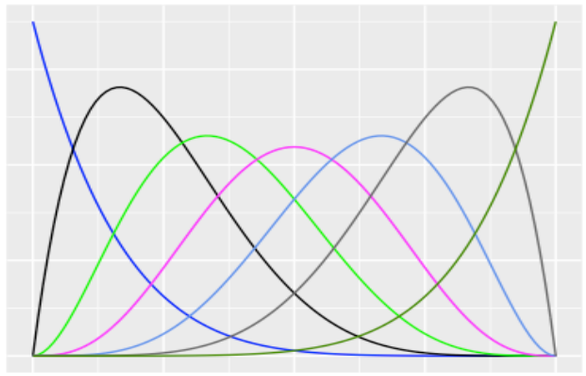
y

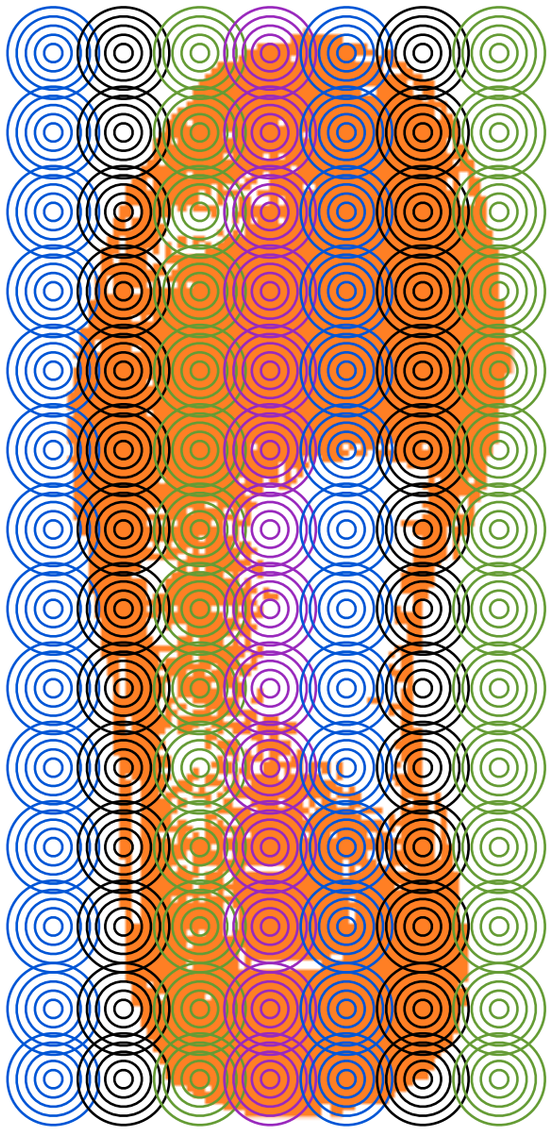
x

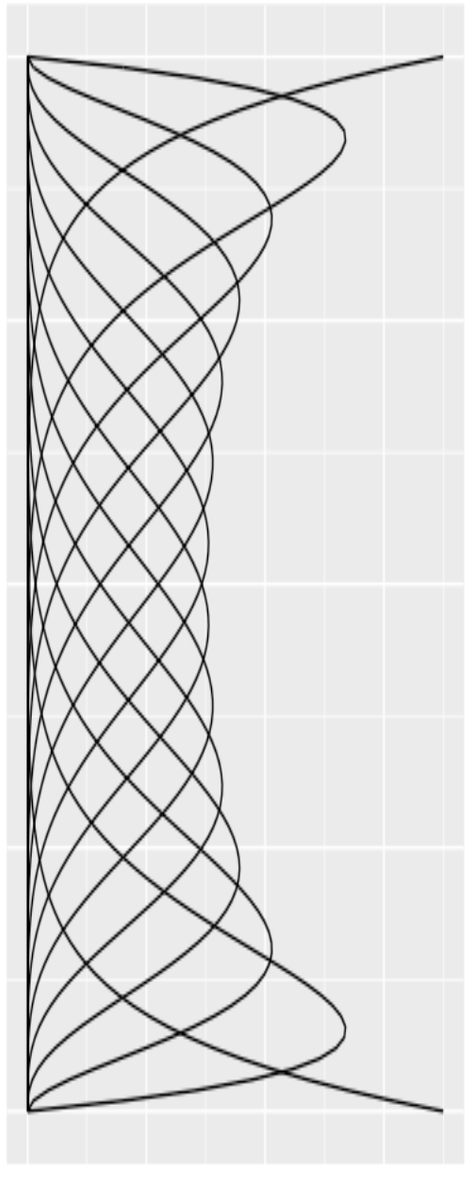


16

Newly Proposed Model







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Controls height of basis function

Depends on:

- Contact Surface
- Location

y

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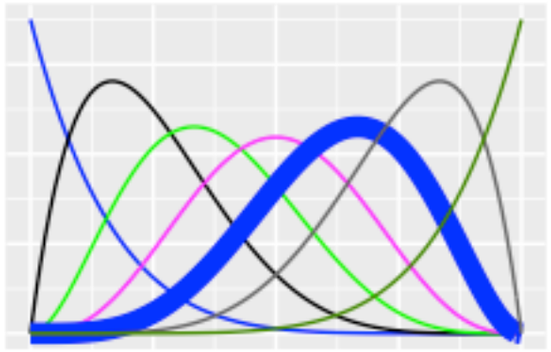

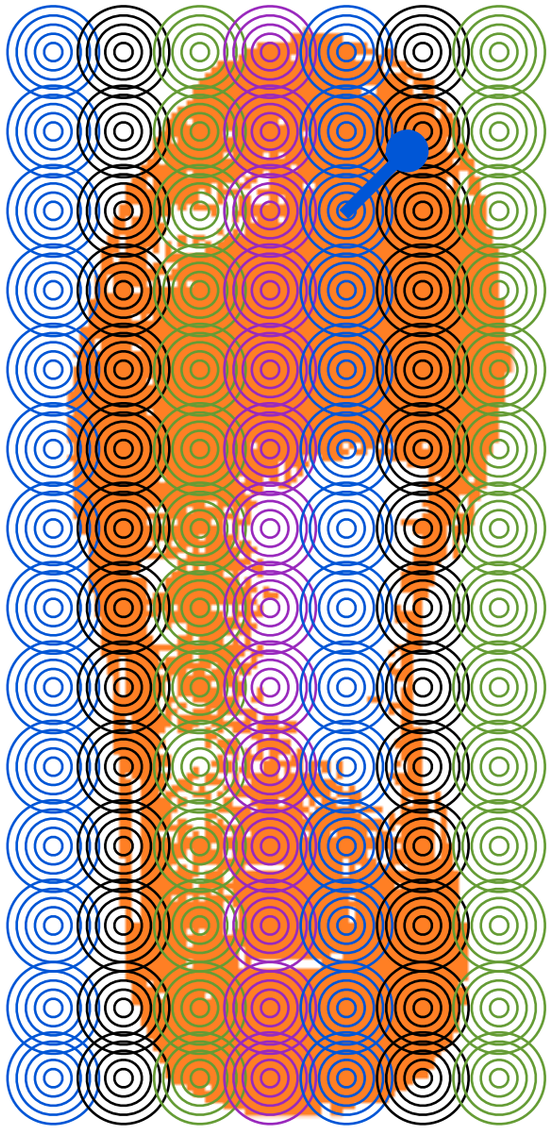

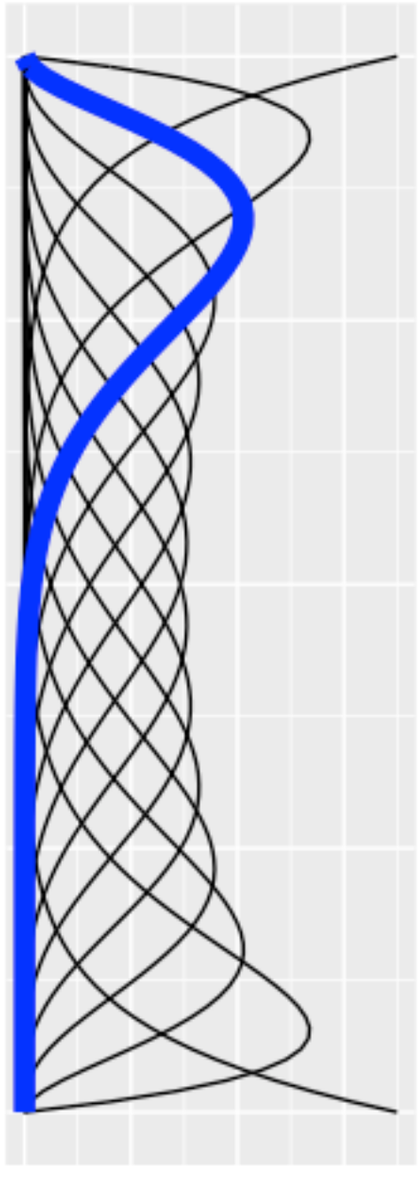

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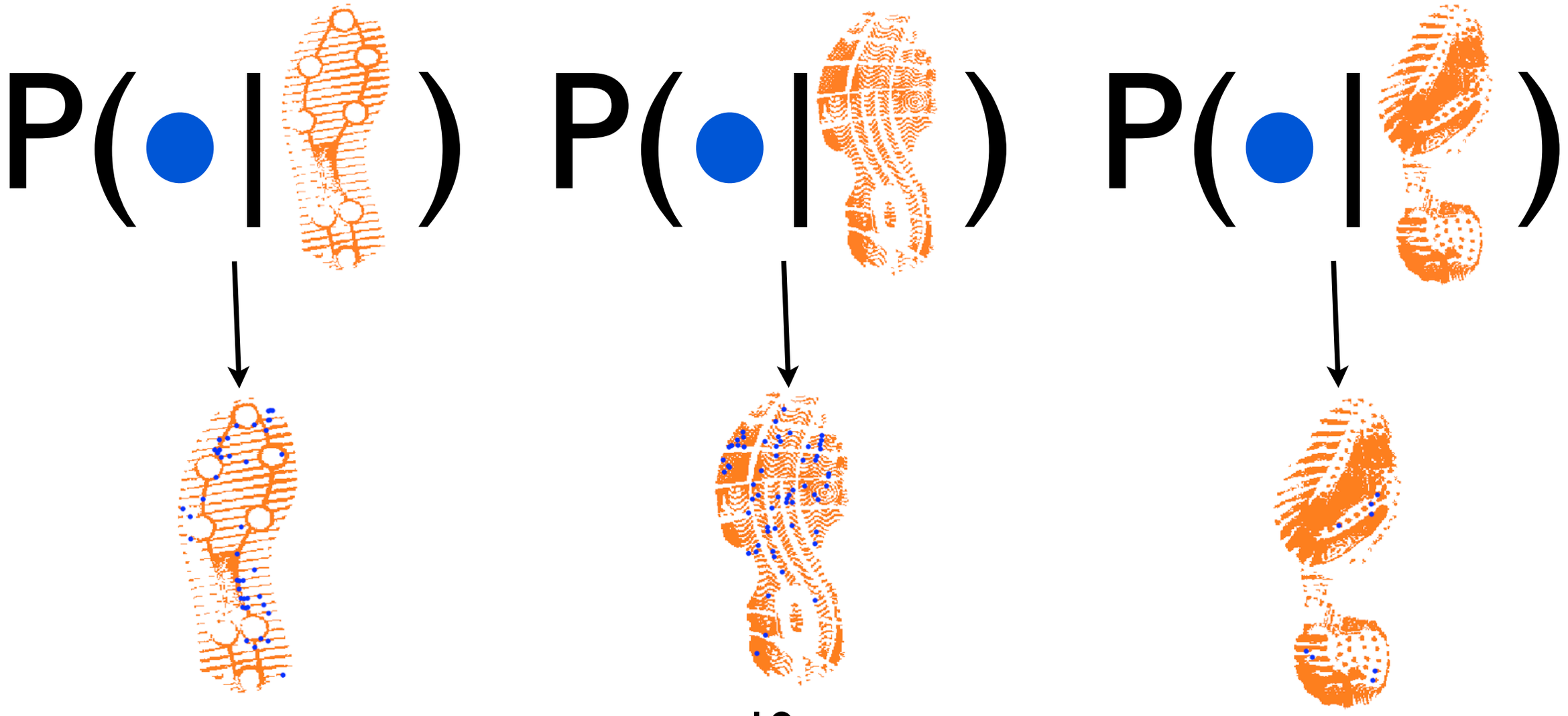

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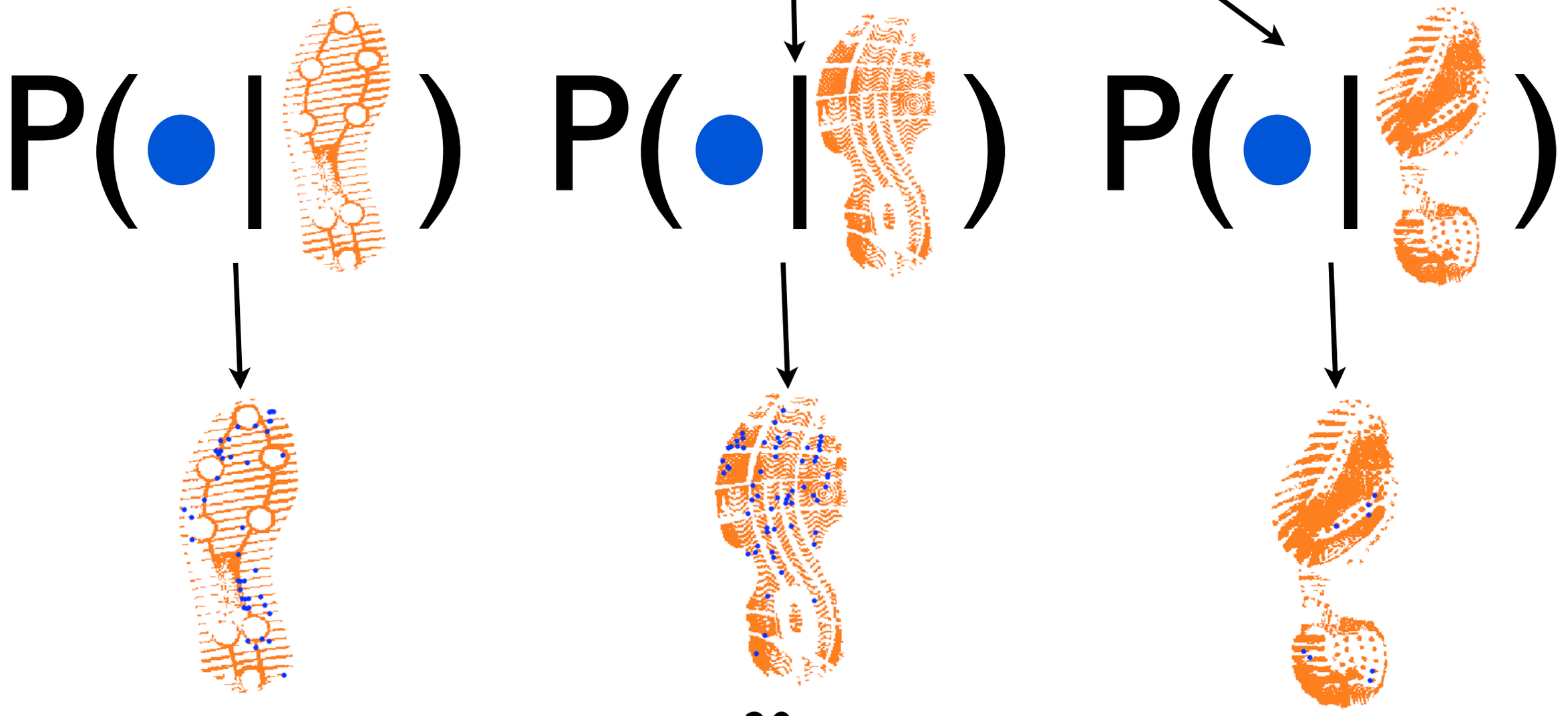

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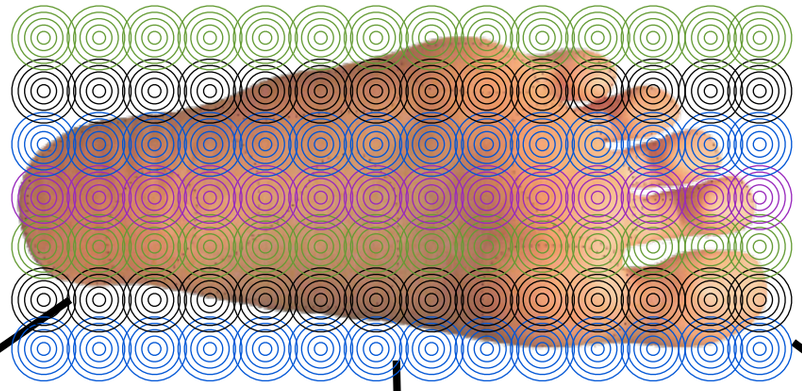

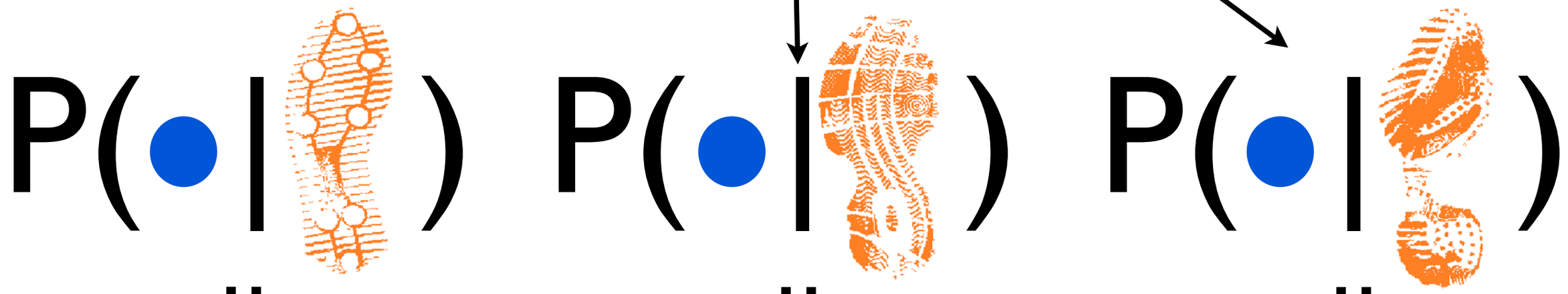

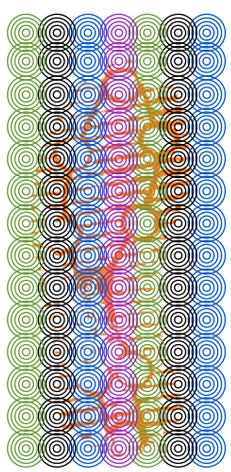

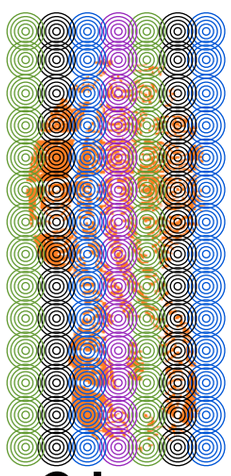

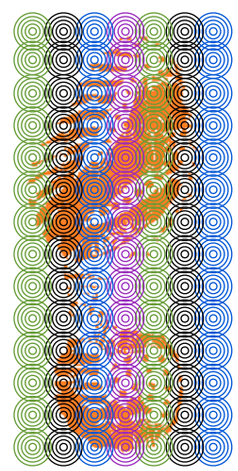

Model for Weights

$$\boxed{\pi_{ij}} = \text{Contact ij} \times \text{Shoe Specific Noise ij} \times \text{Foot ij}$$

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Six levels depending on nearby contact intensity

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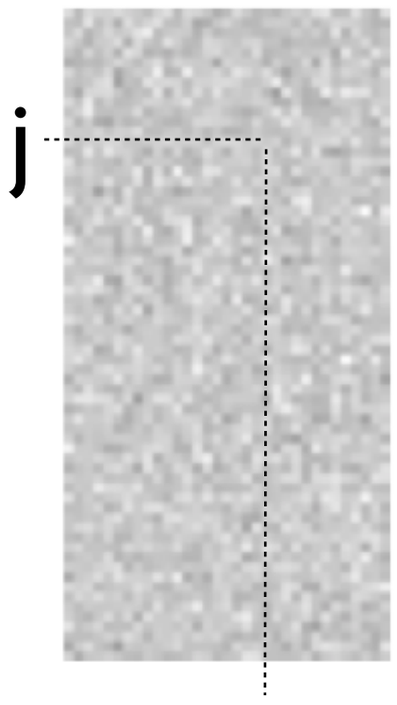

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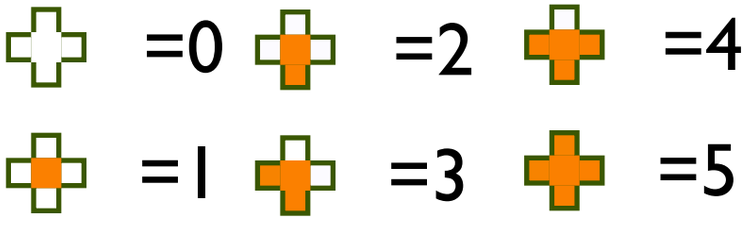

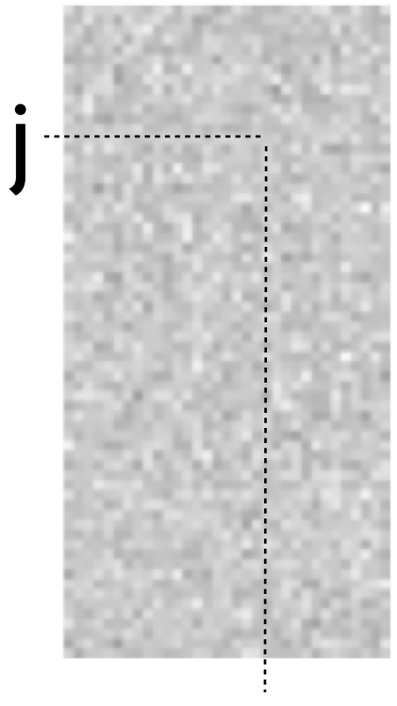

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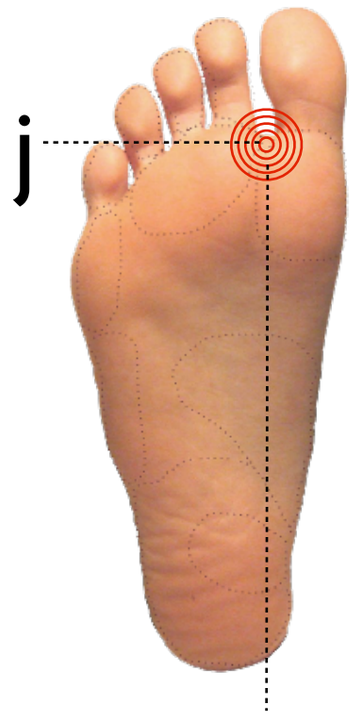
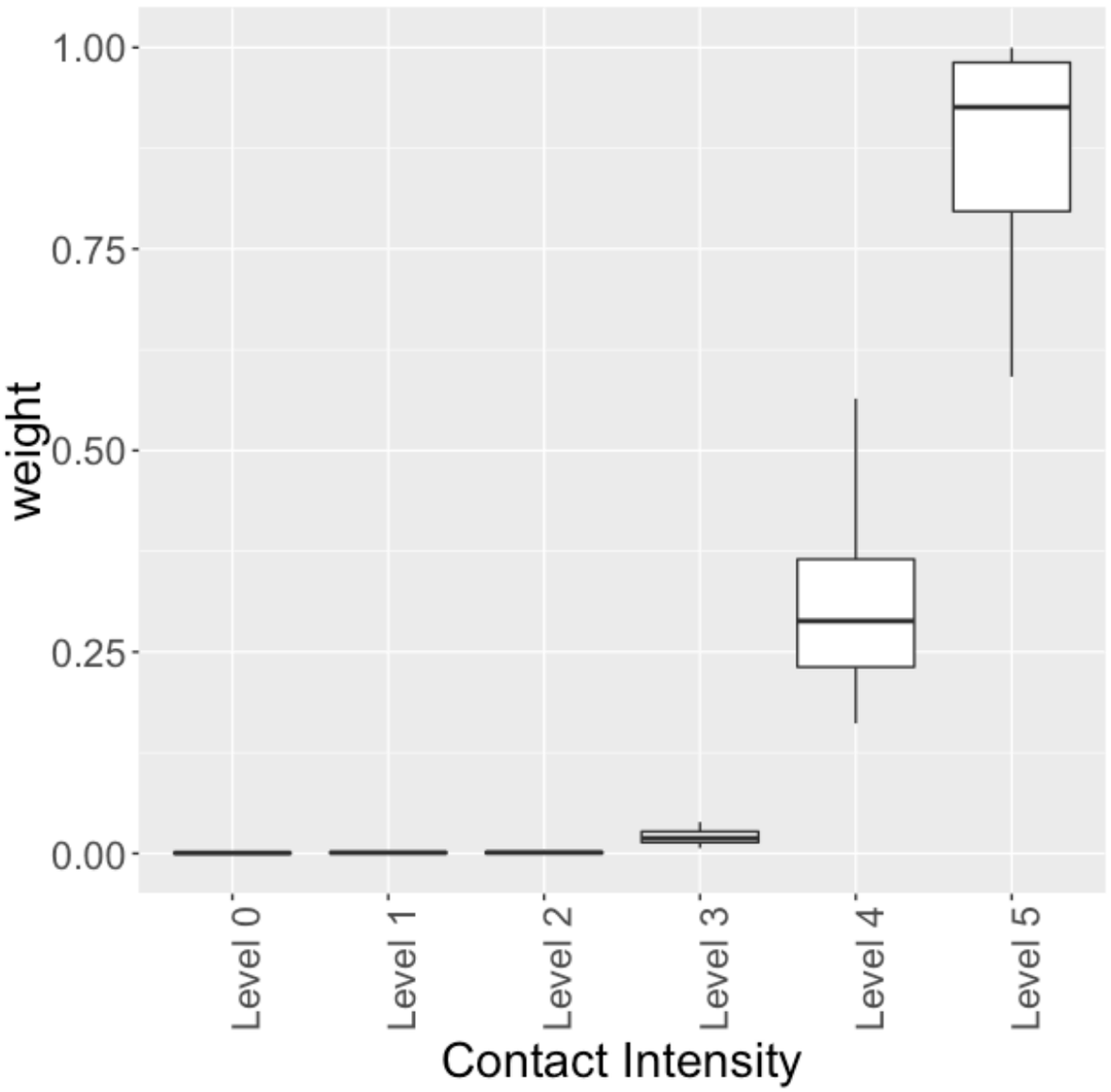
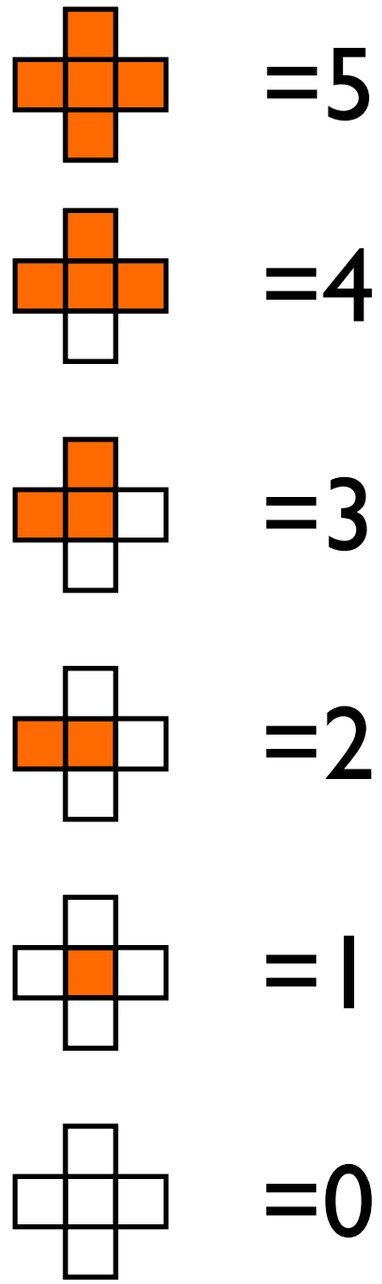


Common across all Shoes

Results of Fit (for 386 shoes)

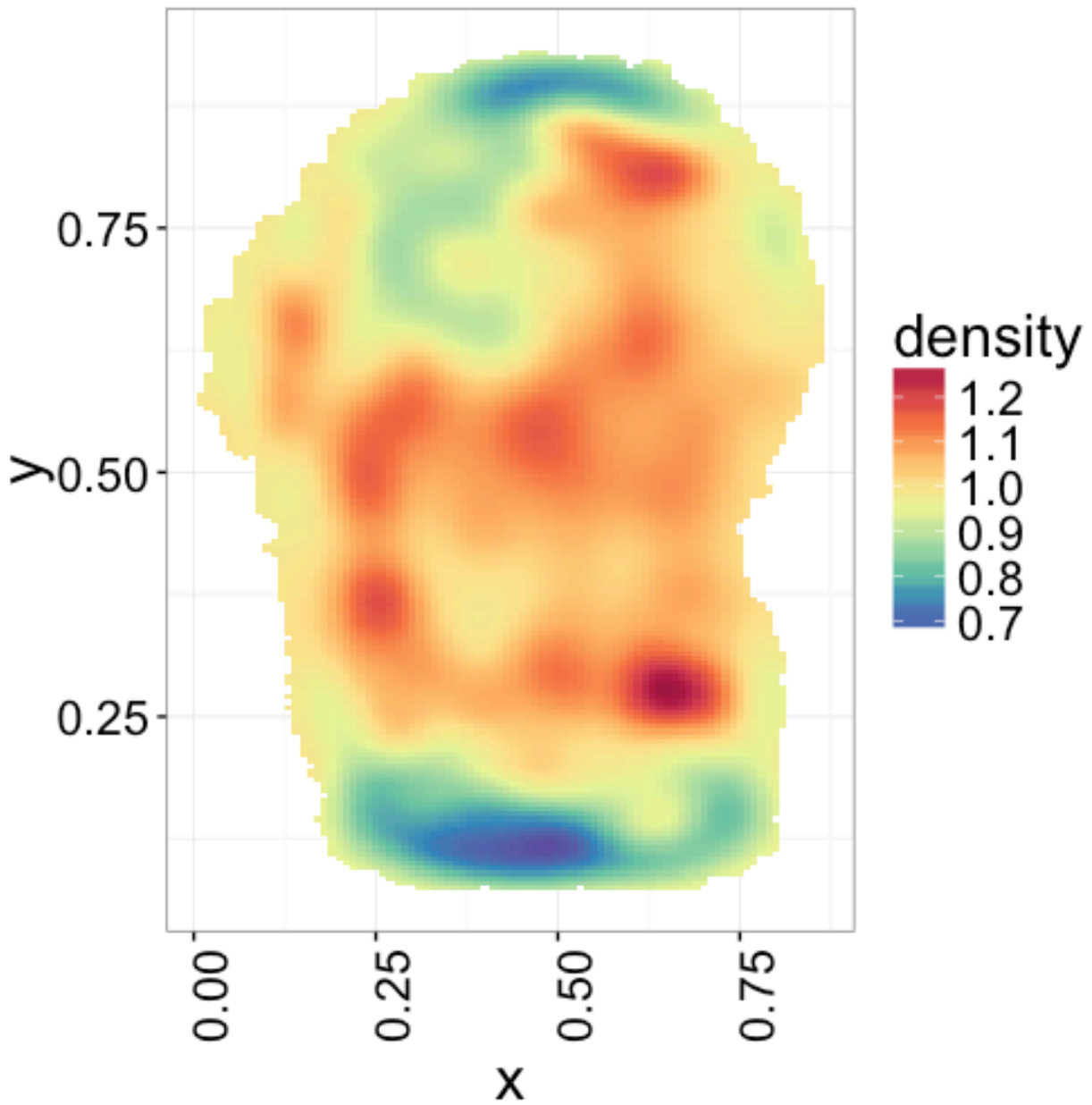
Contact Surface Variables





Results

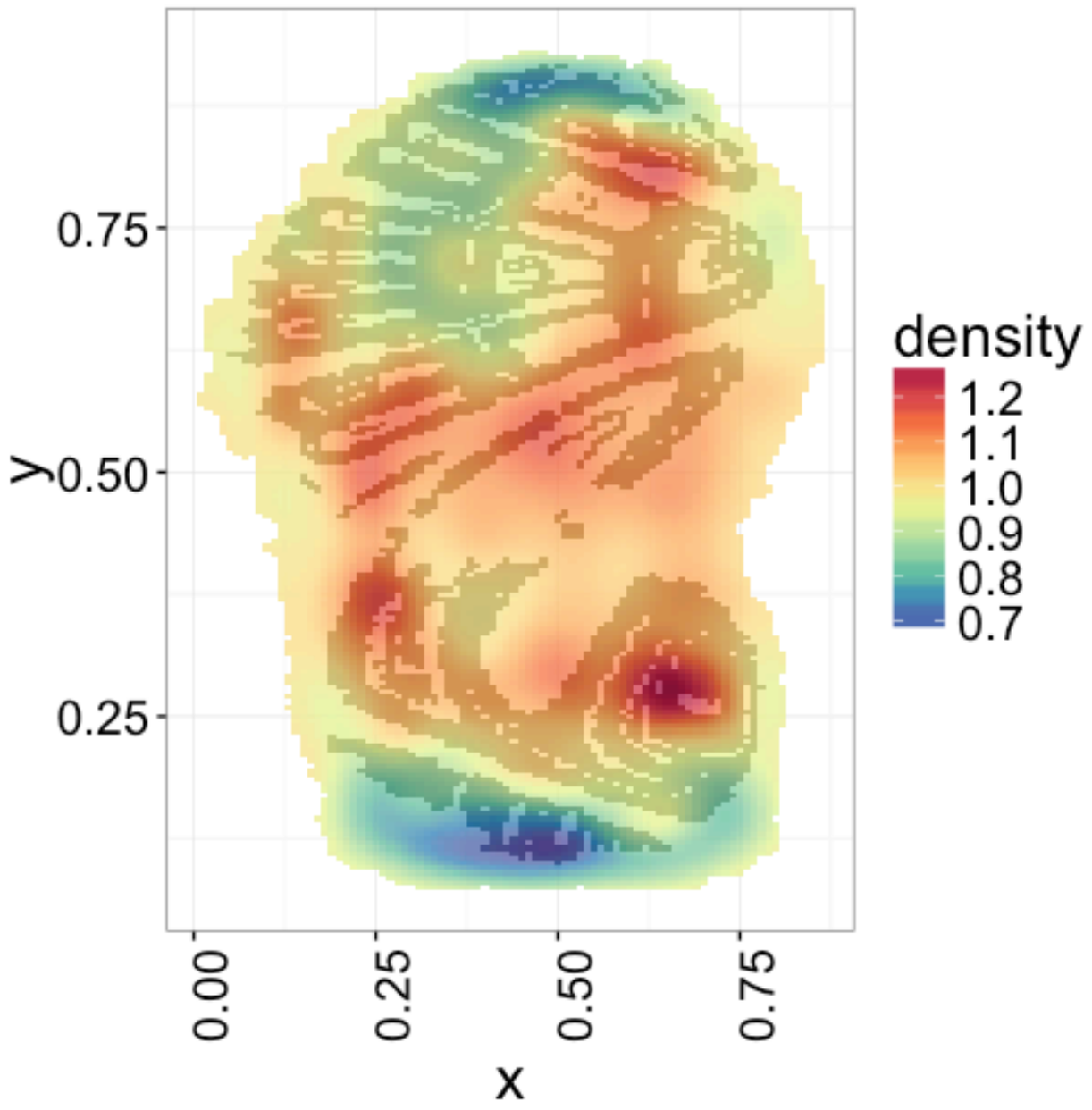
The "Foot" Component



Results

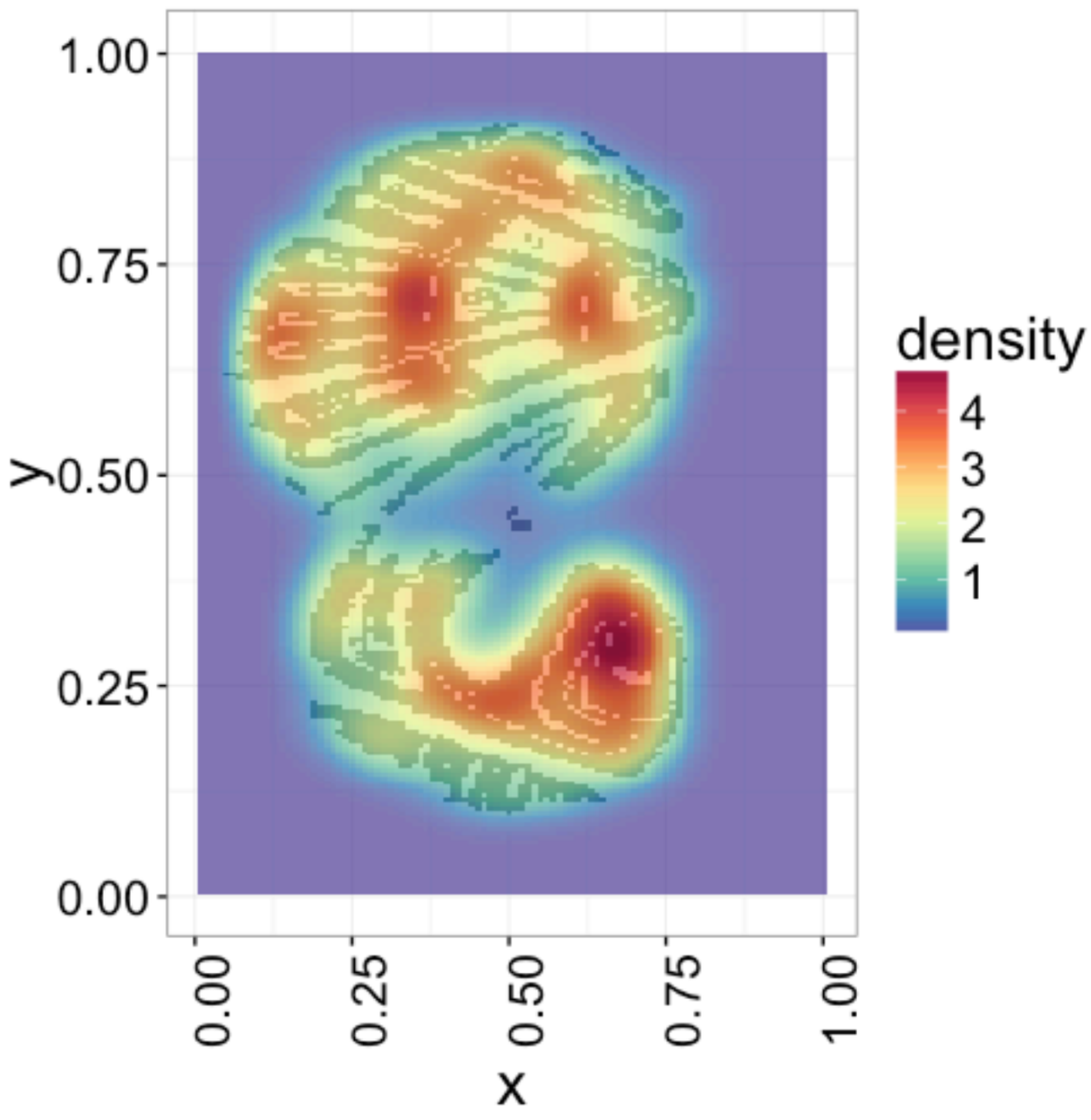
The "Foot" Component

with an example shoe



Results

Example Predictive Distribution for Shoe



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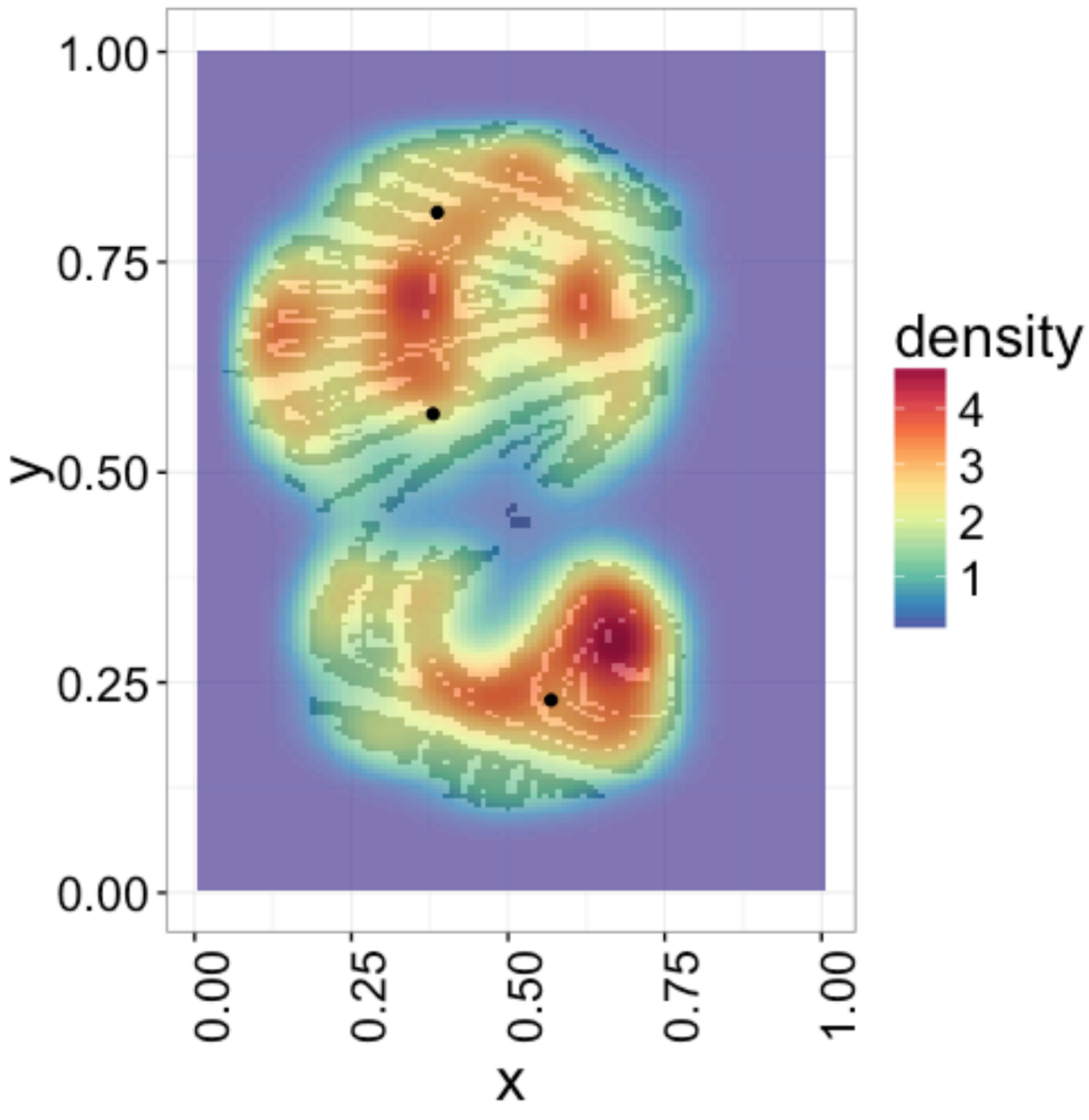
Example Predictive Distribution for Shoe

Actual Accidental Locations



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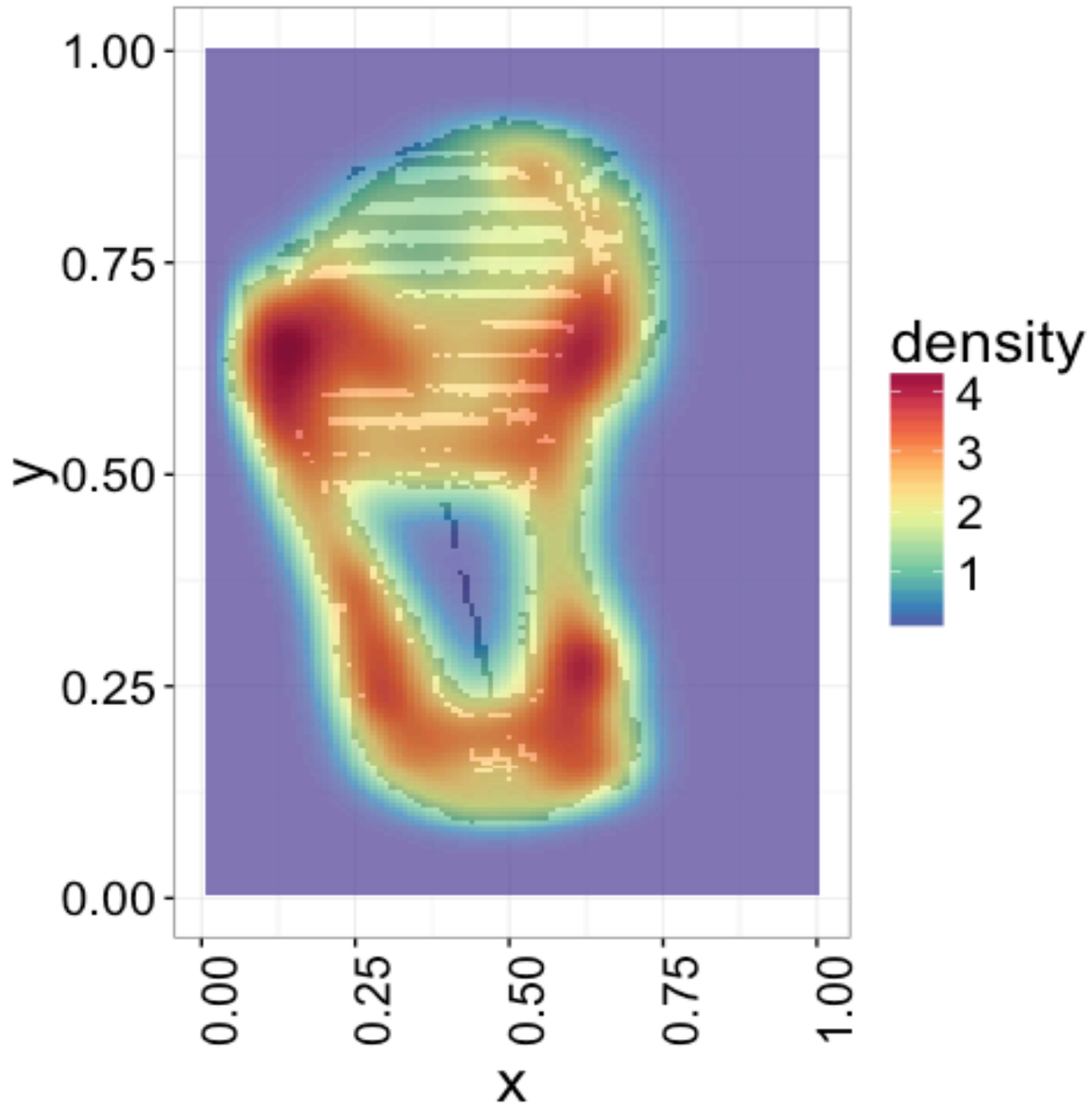

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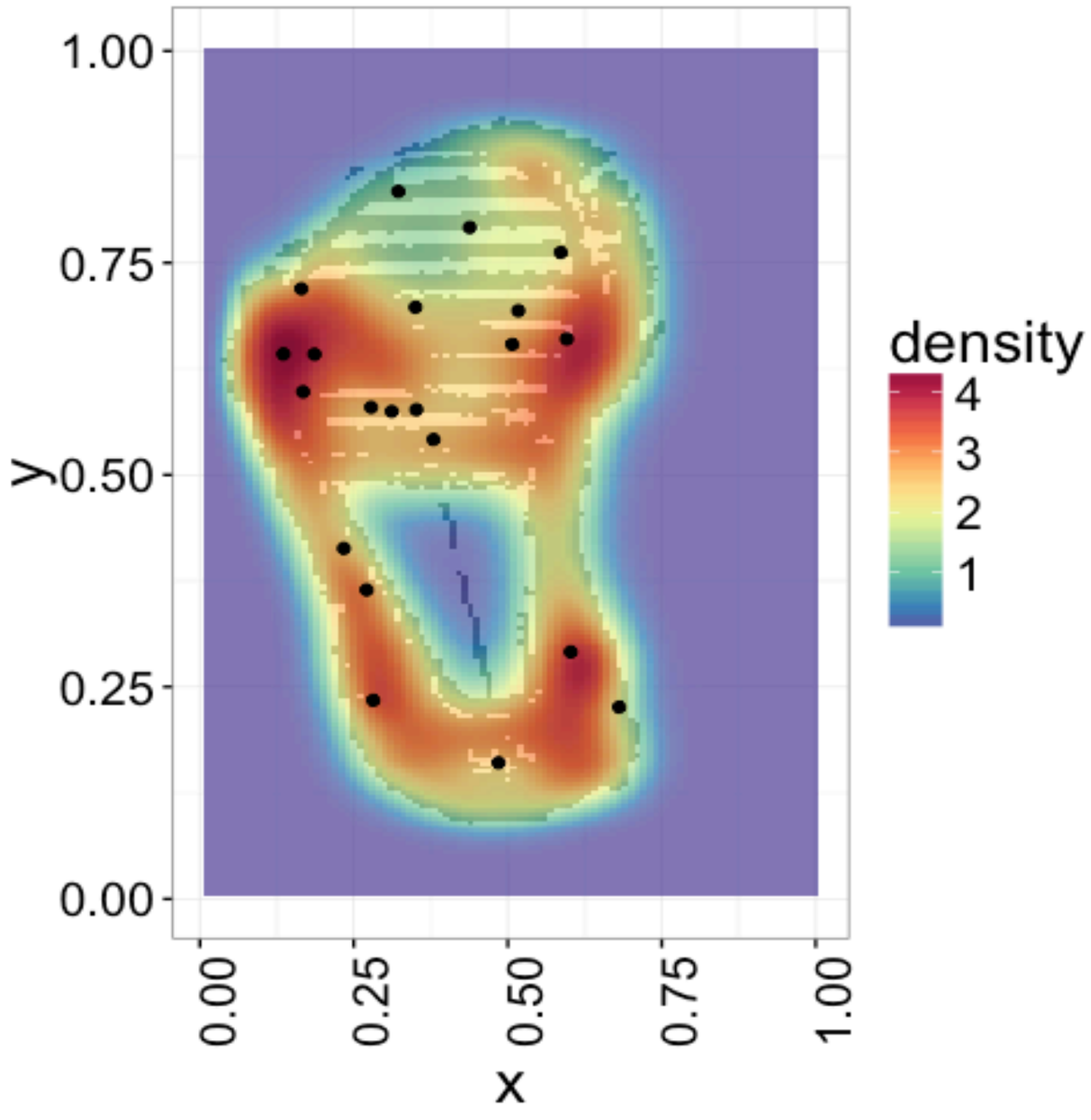
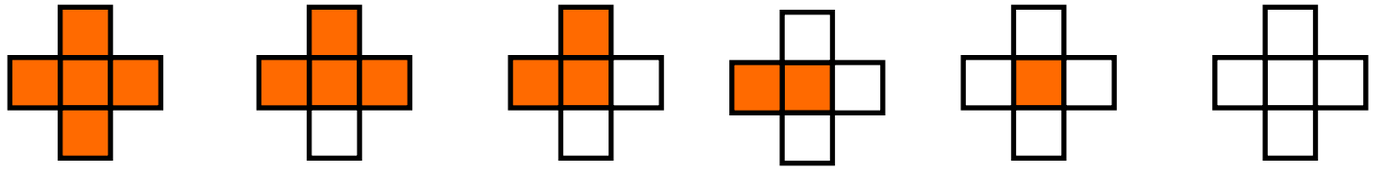
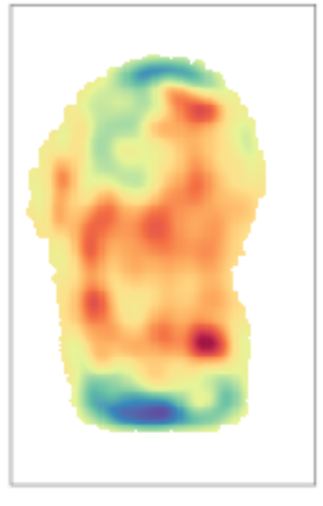


Conclusion

We developed a model for accidentals given contact surface

It features the contact surface variables and a “foot” variable





Thank you

Sarena Wiesner

Yoram Yekutieli

Yaron Shor

csafe

Center for Statistics and Applications in Forensic Evidence

NIST

National Institute of Standards and Technology

U.S. Department of Commerce