Matching Randomly Acquired Characteristics in Footwear Impressions

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Purpose

• Obtain a quantitative similarity score for footwear impression comparisons.
Class characteristics

Vans 11
Skechers 9.5
Vans 10.5
Vans 11
Class Characteristics

- Design (pattern)
- Size
- General wear
Randomly Acquired Characteristics (RACs)

Definition
A RAC feature is a feature on a shoe outsole resulting from random events.

- RACs are not replicated in every impression.
- Research has demonstrated that the chance duplication of even one characteristic’s position, orientation, shape and size on another shoe of the same size and design would be rare.
Randomly Acquired Characteristics (RACs)

**Types**
Include but not limited to:
- Cuts
- Scratches
- Tears
- Holes
- Foreign objects
- Abrasions
- Debris
Workflow of RACs Comparison

Test impression

Global registration

RACs marking

RAC patches RAC locations

Local registration

Comparison

RAC patches RAC locations

Score

Workflow of RAC extraction and comparison
Global Registration

Test impression

Questioned impression

Global registration result
Local Registration

Global registration result

Test

Questioned

Local registration

Test  Questioned
Registration Methods

Global Registration
• Principal Axes and Mutual Information
• Point Configuration Methods

Local Registration
• Mutual Information

\[
I(X; Y) = H(X) + H(Y) - H(X, Y)
\]

\[
I(X; Y) = \sum_x \sum_y p(x, y) \log \frac{p(x, y)}{p(x)p(y)}
\]
Impression comparison based on RACs

Test

Questioned1 (Q1) (Mated)

Questioned (Q2) (Non-mated)
Impression comparison based on RACs

Test

Q1 (Mated)

Q2 (Non-mated)
RACs Comparison

Comparison metric
• Normalized cross correlation

\[ r = \frac{\sum_m \sum_n (A_{mn} - \bar{A})(B_{mn} - \bar{B})}{\sqrt{(\sum_m \sum_n (A_{mn} - \bar{A})^2)(\sum_m \sum_n (B_{mn} - \bar{B})^2)}} \]

Comparison scores

| RAC No. | 1    | 2    | 3    | 4    | 5    | 6    | 7    | 8    | 9    | 10   | 11   | 12   | 13   | 14   | 15   | Average |
|--------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|--------|
| Q1 vs Test | 0.9400 | 0.8917 | 0.8595 | 0.8617 | 0.7164 | 0.8815 | 0.9105 | 0.8687 | 0.8212 | 0.9152 | 0.9110 | 0.8790 | 0.7357 | 0.9155 | 0.6926 | **0.8534** |
| Q2 vs Test | 0.4039 | 0.5283 | 0.4779 | **0.8714** | 0.8861 | 0.3849 | 0.3624 | 0.6873 | 0.3329 | **0.8443** | 0.5301 | 0.4497 | 0.3954 | **0.8281** | 0.2596 | **0.5495** |
Impression comparison based on RACs

Test

Q1 (Mated)

Q2 (Non-mated)

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Performance of the comparison algorithm

Errorbar of similarity value of mated and non-mated

- mated
- non-mated

Similarity

RAC No.
Performance of the comparison algorithm

Distribution of similarity value of match and non-match

Score

Frequency

Forensics@NIST

#NISTForensics
Performance of the comparison algorithm

ROC for RACs

AUC = 0.97681
Conclusion

Include more information of RACs
RAC comparison score can help us to give a conclusion of the comparison between questioned impression and known impression according to SWGTREAD range of conclusions scale. The comparison approach used in this presentation is only based on the pixel values of corresponding pixels. The other information of the RACs such as shape, orientation, size will also be incorporated into the similarity score.

Find better methods to combine similarity scores of all RAC pairs into a final score
Different RACs have different importance to the final score due to their different size, shape complexity, orientation and etc.
Reference

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