Dr. Muhammad Hassan  
PhD in  
Applied Computer Technologies, College of Computer Science and Technology,  
Jilin University, China

Supervised by  
Prof. Zhou You, Jilin University  
Email: zyou@jlu.edu.cn

Co-Supervisor  
Prof. Wang Yan (Jilin University, China, Email: wy6868@jlu.edu.cn)  
Prof. Xu Dong (University Missouri USA, Email: xudong@missouri.edu)  
Prof. Wang Di (NTU Singapore, Email: wangdi@ntu.edu.sg)  
Prof. Wei Pang (University Edinburgh UK, Email: w.pang@hw.ac.uk)
<table>
<thead>
<tr>
<th>Degree</th>
<th>Major</th>
<th>University/School</th>
<th>From</th>
<th>To</th>
</tr>
</thead>
<tbody>
<tr>
<td>PhD</td>
<td>Applied Computer Technology (AI, Machine learning)</td>
<td>Department of Computer Science and Technology, Jilin University, China</td>
<td>2018</td>
<td>2022</td>
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<tr>
<td>MPhil</td>
<td>Image processing</td>
<td>Department of Computer Science and Information Technology, University of Malakand, Pakistan</td>
<td>2013</td>
<td>2016</td>
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<tr>
<td>MSc</td>
<td>Computer Science</td>
<td>Department of Computer Science, University of Peshawar, Pakistan</td>
<td>2007</td>
<td>2010</td>
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<tr>
<td>BSc</td>
<td>Computer Science + Math</td>
<td>Government Post Graduate College Timargara, Pakistan</td>
<td>2005</td>
<td>2007</td>
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<tr>
<td>FSc</td>
<td>Pre-Engineering</td>
<td>Government Post Graduate College Timargara, Pakistan</td>
<td>2003</td>
<td>2007</td>
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Cutting-edge Technologies for Low-quality Shoeprint Images and Applications
Outline

• Overview

• Existing works

• Key Contributions
  • Large-scale Shoeprint Dataset with Variety of Dataset Versions
  • Systematic Association Among Traits, Gait, and Footprints using ML
  • Shoeprint Reconstruction
  • Restorable-inpainting
  • Super-Resolution (no Higher resolution version)

• Conclusion and

• Future Challenges
Overview

• **Low quality images (Shoeprints)**
• Contact of footwear tread with the ground surface
• Reflecting the pressed regions (**pressure**) of footwear while standing, walking, or running.
• Found in critical environment e.g., **Forensic scenes**
• Controlled environment (Everspry Outsole Scanner) but have similarities with realistic circumstances.
• **Inconsistency** in patterns, shape, appearance, textures, designs, and wear-effects
• Found in **poor quality**.
Existing work

• Low quality images, such as Shoeprints processing: through manual [1], semi-automated [2,3], and automated [4-8] methods.
• Shoeprints matching [9], recognition [10], and reconstruction [7, 11].
• Forensic podiatry [6,9,12–14], biological trait investigation [15], gender [14,16,17], and body morphology examination [18].
• Existing work: based on morphological features (L,W), hand-crafted, and conventional algorithms [14–18].
Key Contributions

• Large-scale Shoeprint Dataset with Variety of Dataset Versions
• Systematic Association Among Traits, Gait, and Footprints using ML
• Shoeprint Reconstruction
• Restorable-inpainting
• Super-Resolution (no Higher resolution version)
First Large Shoeprints Dataset

Dataset: 100,000 images, 50,000, age 7-to- 80 years.

Seven Dataset versions

Following is the list of generated datasets:

- **Dataset-A**: unprocessed and original shoeprints,
- **Dataset-B**: scale/ruler (divert training) and poor-quality images (75% abrasive) are discarded manually,
- **Dataset-C**: contains only left shoeprints,
- **Dataset-D**: contains only right shoeprints,
- **Dataset-E**: Pairwise in natural orientation
- **Dataset-F**: for gender-based classification and age prediction, and
- **Dataset-G**: male and female ratio-based balance dataset (augmented).

<table>
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<tr>
<th>Dataset</th>
<th>No. of Samples</th>
<th>Dimension (H x W)</th>
<th>LSO</th>
<th>RSO</th>
<th>BLR</th>
<th>Ruler</th>
<th>Gender</th>
<th>Description</th>
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<td>224x112</td>
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<td>-</td>
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<td>✓</td>
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<td>Original dataset</td>
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<td>Dataset-B</td>
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<td>✓</td>
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<td>224x112</td>
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<td>-</td>
<td>Left shoeprints</td>
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<tr>
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<td>224x112</td>
<td>-</td>
<td>✓</td>
<td>-</td>
<td>-</td>
<td>Right shoeprints</td>
<td></td>
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<td>224x224</td>
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<td>Dataset-G</td>
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<td>Balance dataset</td>
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Computer applied technology, College of Computer Science and Technology, Jilin University, China
Age and Gender Estimation Model

Comparative modalities Results

<table>
<thead>
<tr>
<th>Networks</th>
<th>Network-Types</th>
<th>MAE</th>
<th>MCS-2</th>
<th>MCS-3</th>
</tr>
</thead>
<tbody>
<tr>
<td>LR-CNN</td>
<td>a-Left-Shoeprints</td>
<td>9.38</td>
<td>11.52</td>
<td>15.16</td>
</tr>
<tr>
<td></td>
<td>b-Right-Shoeprints</td>
<td>9.70</td>
<td>12.12</td>
<td>15.70</td>
</tr>
<tr>
<td></td>
<td>c-Left-to-Right Shoeprints</td>
<td>9.51</td>
<td>10.49</td>
<td>13.78</td>
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<tr>
<td>FM-CNN</td>
<td>a-Early-Fusion</td>
<td>9.48</td>
<td>10.19</td>
<td>13.60</td>
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<tr>
<td></td>
<td>b-In-Fusion</td>
<td>9.78</td>
<td>11.19</td>
<td>14.74</td>
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<tr>
<td></td>
<td>c-Late-Fusion</td>
<td>9.45</td>
<td>9.91</td>
<td>13.15</td>
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<tr>
<td>MM-CNN</td>
<td>a-Early-Sharing</td>
<td>8.99</td>
<td>11.09</td>
<td>14.59</td>
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<tr>
<td></td>
<td>b-Middle-Sharing</td>
<td>9.10</td>
<td>10.74</td>
<td>14.31</td>
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<tr>
<td></td>
<td>c-Late-Sharing</td>
<td>9.72</td>
<td>9.96</td>
<td>13.35</td>
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<td>ShoeNet</td>
<td></td>
<td><strong>9.21</strong></td>
<td><strong>13.06</strong></td>
<td><strong>16.80</strong></td>
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Age Estimation Results

<table>
<thead>
<tr>
<th>Age Ranges in Years</th>
<th>MAE Mean Absolute Error</th>
<th>MCS-2</th>
<th>MCS-3</th>
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<tbody>
<tr>
<td>10-80</td>
<td>9.21</td>
<td>13.05</td>
<td>16.80</td>
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<tr>
<td>20-50</td>
<td>7.51</td>
<td>15.16</td>
<td>19.55</td>
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<tr>
<td>25-45</td>
<td>6.44</td>
<td>17.59</td>
<td>22.00</td>
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<tr>
<td>10-20</td>
<td>10.80</td>
<td>9.24</td>
<td>11.12</td>
</tr>
<tr>
<td>21-30</td>
<td>6.77</td>
<td>17.86</td>
<td>22.67</td>
</tr>
<tr>
<td>31-40</td>
<td>6.23</td>
<td>16.52</td>
<td>21.38</td>
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<tr>
<td>41-50</td>
<td>10.05</td>
<td>9.64</td>
<td>12.87</td>
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<tr>
<td>51-80</td>
<td>18.82</td>
<td>2.4</td>
<td>3.4</td>
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</table>

Statistical results for age estimation in different age groups.

<table>
<thead>
<tr>
<th>Network</th>
<th>%MAE</th>
<th>CS0</th>
<th>CS1</th>
<th>CS2</th>
<th>CS3</th>
<th>MCS-2</th>
<th>MCS-3</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLF</td>
<td>11.2</td>
<td>4.3</td>
<td>13.4</td>
<td>20.69</td>
<td>27.09</td>
<td>12.71</td>
<td>16.305</td>
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<tr>
<td>MSE</td>
<td>11.07</td>
<td>4.04</td>
<td>12.84</td>
<td>19.49</td>
<td>25.73</td>
<td>12.12</td>
<td>15.52</td>
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</table>

Gender-based classification report with significant (86.07%) accuracy.

<table>
<thead>
<tr>
<th>Classification</th>
<th>Precision</th>
<th>Recall</th>
<th>F1-score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>0.836</td>
<td>0.8973</td>
<td>0.8656</td>
</tr>
<tr>
<td>Female</td>
<td>0.8892</td>
<td>0.8240</td>
<td>0.8554</td>
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<tr>
<td>Testing accuracy</td>
<td>86.07%</td>
<td></td>
<td></td>
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</tbody>
</table>

Pressure Distribution with Age Progression

Male and Female Pressure Distribution

(a) 

(b)
Hassan, Muhammad, Yan Wang, Wei Pang, Di Wang, Daixi Li, You Zhou, and Dong Xu. Deep Learning Model for Human-Intuitive Shoeprint Reconstruction, in Expert Systems With Applications (minor review), IF=6.945, (中科院1区)
### Geometric Score

![Geometric Score Graphs]

**Empirical Cumulative Density Function (ECDF)**

![ECDF Graphs]

### Human visual inspection

![Visual Inspection Images]

**RBA(%)** = $\frac{S^2}{n} \times 100$

<table>
<thead>
<tr>
<th></th>
<th>Rank-1 (Perfect)</th>
<th>Rank-2 (Excellent)</th>
<th>Rank-3 (Good)</th>
<th>Rank-4 (Average)</th>
<th>Rank-5 (Not good)</th>
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<tbody>
<tr>
<td>Original</td>
<td>109</td>
<td>220</td>
<td>119</td>
<td>54</td>
<td>18</td>
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<tr>
<td>ShocRec</td>
<td>352</td>
<td>91</td>
<td>29</td>
<td>52</td>
<td>6</td>
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<tr>
<td>Pix2Pix-GAN</td>
<td>15</td>
<td>23</td>
<td>108</td>
<td>121</td>
<td>233</td>
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<tr>
<td>ResNet-GAN</td>
<td>9</td>
<td>37</td>
<td>87</td>
<td>260</td>
<td>107</td>
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<tr>
<td>LS-GAN</td>
<td>15</td>
<td>129</td>
<td>157</td>
<td>63</td>
<td>136</td>
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</table>

![RBA Images]

**Ranked based score (RBA)**

21.80% 70.40% 3.00% 3.00% 1.80%
Restorable-Inpainting

DeepShoePaint vs. SOTA

Results

Single occlusion

Multiple occlusions

Original

Reconstructed

Masked shoeprint

(a)

(b)
Mean Probability Density-Function based Histogram (MPHC)

Static Patching: 
- Original shoeprints
- Inpainted shoeprints

Dynamic Patching: 
- Original shoeprints
- Inpainted shoeprints

Regression based on density function

St-M Dy-M

Empirical cumulative distribution function (ECDF)

Percent inpainting accuracy via RMSE, PSNR, and SSIM

\[ \text{Acc} = \left( \frac{1}{n} \sum_{j=0}^{n} R\{H(J_j^{px} \otimes M_j(\%)); I_j^{px}\} \right)_{j=1}^n \]

Low-to-high range for NC-Correlation, UQI, and SCC is [0, 1], and for PSNR-B is [20, 50].

<table>
<thead>
<tr>
<th>Masking</th>
<th>NC-Correlation</th>
<th>UQI</th>
<th>SCC</th>
<th>PSNR-B</th>
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<tbody>
<tr>
<td>St-M</td>
<td>0.825188769</td>
<td>0.686077308</td>
<td>0.45784598</td>
<td>25.23651387</td>
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<tr>
<td>Dy-M</td>
<td>0.869630208</td>
<td>0.833612737</td>
<td>0.769742493</td>
<td>30.25184098</td>
</tr>
</tbody>
</table>

Geometrics score

Regression based on density function

Percent inpainting accuracy via RMSE, PSNR, and SSIM
Hassan, Muhammad, Yan Wang, Wei Pang, Di Wang, Daixi Li, You Zhou, and Dong Xu. IPAS-Net: A deep-learning model for generating high-fidelity shoeprints from low-quality images with no natural references, Journal of King Saud University - Computer and Information Sciences (JKSUJ), (中科院1区), IF=13.473
Conclusion

• **First large dataset** (100,000 image) with different **versions** to train DL modalities and **forensic** applications.
• **Systematically** association of biological **profile** (i.e., aging and gender), **gait**, and **shoeprints**.
• Estimation of **Age** and **Sex**.
• **Pressure distributions** and variations with **Aging** and **Sex**.
• **Shoeprint reconstruction** (missing borders, scratches, patterns, plausible pixels generation) via **DL**.
• **Restorable-inpainting** (Restoring ability).
• Generation of **high-fidelity shoeprints** having no natural **HR images**.
Future Directions

• **Other biological profiles** (height, weight, ethnicity, etc.) estimation can be studied as future direction.
• The **transgender** option can be added in the future study.
• **Asymmetric features** can be systematically associated to a person's gait.
• **Asymmetric features** between left and right shoeprint can be employed in shoeprint reconstruction.
• **Enhancement** in Restoration and Reconstruction.
• **Shoe types** can be included in the dataset to robustly train DL models.
• DL models for addressing **poor-quality** images.
• **Restorable-inpainting** can be extended to **large size** holes.
• **Natural degradation** via DL models.
• GUV-Net results can be improved with **denoising and deblurring** in HR space.
• Application of the proposed model to other realistic datasets including stellate.
List of Research Articles

1. **Muhammad Hassan**, Yan Wang, Pang Wei, Di Wang, Daixi Li, You Zhou, and Dong Xu, IPAS-Net: A deep-learning model for high fidelity shoeprints from low-quality images with no natural references, Journal of King Saud University: Computer and Information Sciences, 10.1016/j.jksuci.2022.03.024, IF=13.473. (中科院1区)


6. **Muhammad Hassan**, Yan Wang, Pang Wei, Di Wang, Daixi Li, You Zhou, and Dong Xu, Deep Learning Model for Human-Intuitive Shoeprint Reconstruction, **Minor Revision** in Expert Systems With Applications, IF= 6.945. (中科院1区)
References