Color Texture Description Based on Holistic and Hierarchical Order-Encoding Patterns

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Motivations

● Most of LBP-based methods were designed for gray. However, color spaces (e.g., RGB or HSV) were shown to be closer to human perception and can be effectively incorporated to describe images.

● Ranks (or orders) of values can effectively describe texture structure or color information.

● Distinguish more distinct intensity patterns (e.g., [1 2 3 4] and [10 20 30 40]) in a color image rather than our recent work SWOBP.
Proposed color descriptor
Holistic color-order encoding

- A central pixel in a three-channel image:

\[ g_c = [g_c^1, g_c^2, g_c^3] \] (6)

- Sort these intensity values and record their color order information:

\[ g_{\text{order}} = [g_{\text{CI}}^1, g_{\text{CI}}^2, g_{\text{CI}}^3] = \text{sort}(g_c) \] (7)

- Holistic order-encoding pattern for each central pixel is defined as:

\[ H2OEP - T = f(g_{\text{order}}) \] (8)

<table>
<thead>
<tr>
<th>Number</th>
<th>( g_{\text{order}} )</th>
<th>Tendency</th>
<th>Attribute</th>
<th>( f(g_{\text{order}}) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>[1, 2, 3]</td>
<td>↑</td>
<td>monotone</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>[3, 2, 1]</td>
<td>↓</td>
<td>monotone</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>[1, 3, 2]</td>
<td>↘</td>
<td>convex</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>[2, 3, 1]</td>
<td>↗</td>
<td>convex</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>[2, 1, 3]</td>
<td>↗</td>
<td>concave</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>[3, 1, 2]</td>
<td>↘</td>
<td>concave</td>
<td>3</td>
</tr>
</tbody>
</table>

Fig. 3: Illumination of the holistic color-order encoding
Hierarchical color-order encoding

- Given the color order:

\[
g_{\text{order}} = [g_{cI}^1, g_{cI}^2, g_{cI}^3]
\]

- Use min ordering, median ordering and max ordering to rearrange color channels.

\[
g_{c,i} = \begin{cases} 
g_c^1, & \text{if } g_{cI}^1 == i \\
g_c^2, & \text{if } g_{cI}^2 == i \\
g_c^3, & \text{if } g_{cI}^3 == i 
\end{cases}
\]  \quad (9)

where \(i = 1, 2, 3\) indicates the index of rearranged color channels after min ordering, median ordering and max ordering. Similarly, we can rearrange all neighboring points and denote them as \(g_{p,i}\)

- The hierarchical order-encoding pattern for each central pixel is defined as:

\[
H2OEP - N_i = \sum_{p=0}^{P-1} s (g_{p,i} - g_{c,i}) 2^p
\]  \quad (10)
Joint histogram representation

- Define the central pixel encoding operator for image $I$ as follows:

$$H_{2OEP} - C_i = s (g_{c,i} - \bar{g}_{c,i})$$ (11)

where $\bar{g}_{c,i}$ is the average value of all $g_{c,i}$ in the $i$-th rearranged color channel for image $I$, and “C” means central pixels.

- Build a 3D joint histogram like CLBP and transform it into a 1D vector denoted as:

$$H_{H2OEP-TCN_i}$$

- Concatenate all the generated histograms:

$$H_{H2OEP} = [H_{H2OEP-TCN_1}, H_{H2OEP-TCN_2}, H_{H2OEP-TCN_3}]$$ (12)
Experiments

● Texture datasets
  ● KTH-TIPS: 10 classes, illumination & scale changes
  ● KTH-TIPS2-b: 11 classes, illuminations, rotations, poses & scales changes
  ● STex: 476 classes, 7616 color images in total
  ● Outex (TC31): 68 classes, resolutions (dpi) changes

● Nearest-neighborhood (NN) classifier with the chi-square distance:

\[
\chi^2(H_1, H_2) = \sum_k \frac{[H_1(k) - H_2(k)]^2}{H_1(k) + H_2(k)}
\]
## Classification results

<table>
<thead>
<tr>
<th>Method</th>
<th>KTH-TIPS</th>
<th>KTH-TIPS2-b</th>
<th>STex</th>
<th>Outex-TC-00031</th>
<th>Dimension</th>
</tr>
</thead>
<tbody>
<tr>
<td>LBP</td>
<td>94.44±0.63</td>
<td>55.82±1.84</td>
<td>82.02±0.58</td>
<td>88.46</td>
<td>1665</td>
</tr>
<tr>
<td>CLBP</td>
<td>94.71±1.93</td>
<td>56.97±0.84</td>
<td>87.65±0.56</td>
<td>84.12</td>
<td>4056</td>
</tr>
<tr>
<td>SLGP</td>
<td>94.04±1.56</td>
<td>53.56±4.54</td>
<td>78.81±0.64</td>
<td>76.76</td>
<td>504</td>
</tr>
<tr>
<td>mGIST</td>
<td>96.20±1.05</td>
<td>53.15±1.77</td>
<td>60.28±0.54</td>
<td>79.60</td>
<td>1536</td>
</tr>
<tr>
<td>mSIFT</td>
<td>92.10±1.36</td>
<td>55.52±2.90</td>
<td>35.85±0.35</td>
<td>44.78</td>
<td>3000</td>
</tr>
<tr>
<td>Full ranking</td>
<td>93.52±0.84</td>
<td>51.00±2.81</td>
<td>64.90±0.32</td>
<td>81.47</td>
<td>720</td>
</tr>
<tr>
<td>maLBP</td>
<td>93.17±1.22</td>
<td>54.36±5.56</td>
<td>86.17±0.60</td>
<td>82.86</td>
<td>1024</td>
</tr>
<tr>
<td>mdLBP</td>
<td>95.12±1.11</td>
<td>58.31±6.04</td>
<td>90.08±0.45</td>
<td>86.39</td>
<td>2048</td>
</tr>
<tr>
<td>LBPC</td>
<td>92.92±1.24</td>
<td>50.74±2.40</td>
<td>75.54±0.57</td>
<td>84.40</td>
<td>256</td>
</tr>
<tr>
<td>SWOBP</td>
<td>95.98±0.99</td>
<td>64.17±2.91</td>
<td>89.53±0.43</td>
<td><strong>93.20</strong></td>
<td>2226</td>
</tr>
<tr>
<td>H2OEP</td>
<td><strong>97.34±0.79</strong></td>
<td><strong>64.18±2.82</strong></td>
<td><strong>92.06±0.33</strong></td>
<td><strong>92.79</strong></td>
<td>1062</td>
</tr>
</tbody>
</table>

**TABLE I: Classification accuracy in percent (mean±standard deviation) on four color texture databases**
THANKS!