Art Forgery Detection using Wavelets

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Introduction

- Handwriting have characteristics like of curve of letters, slant, peculiar modifications to certain letters etc.
- Wavelets can capture the edge information.
- Wavelet transforms of different handwriting samples will have different statistical properties

We capture the differences and detect forgery by studying the statistical properties of wavelet coefficients

Steps involved in Detection

Procedure is broadly divided into 6 step

1. Image is first divided into 8 parts each of which is 2 level wavelet decomposed.
2. For pixels $LH1$, $HL1$ and $HH1$ as shown in Figure neighbours are selected.
3. Each pixel is linearly predicted in terms of these neighbouring pixels.
4. Error is calulated between the value of the pixel and the prediction.
5. Skewness is calculated for error and prediction coefficient vectors.
6. Same process is repeated for other image and then comparison is done using ANOVA test

Image Division and Wavelet decomposition

1. Image division
   - Since we are dealing with forged handwriting the images are divided along the columns.
   - The division is done in fixed number of parts for each image
2. Wavelet Decompostion
   - Each subimage is 2 level wavelet decomposed [2] using the “Daubechies wavelet” of lenght 4, to obtain seven subbands $LL2$, $LH2$, $HL2$, $HH2$, $LH1$, $HL1$, $HH1$.
   - edge information is a feature of an image which is in general varies with different images which high pass subbands capture.

Neighbour Selection and Linear Prediction

Since we are interested in the first level high pass subbands we select neighbours of pixels in these subbands. The rule for selecting the neighbouring pixels depends upon the location of the pixel in consideration. If p denotes the pixel we are considering then we consider the 9 neighbours. In each of these cases 4 neighbours of p are n_{ip} for $i = 1, 2, 3, 4$ which are the immediate neighbours that share a common edge with the pixels.Then we have the Predictions as linear combinations of these neighbour pixels

Neighbour Selections

We have the following neighbours

1. When the pixel $h \in LH_1$ and $h \equiv (x, y)$. In this case the following are the additional 5 neighbours
   - Vertical Cousin $v_h \in HL_1$ which has coordinates $(x + \frac{N}{2}, y - \frac{N}{2})$
   - Diagonal cousin $d_h \in HH_1$ which has coordinates $(x + \frac{N}{2}, y)$
   - Parent $P_h \in HL_2$ which has coordinates $(\frac{x}{2}, \frac{y}{2})$
   - Vertical Aunt $V_h \in HL_2$ which has coordinates $(\frac{x}{2} + \frac{N}{4}, \frac{y}{2} - \frac{N}{4})$
   - Diagonal Aunt $D_h \in HH_2$ which has coordinates $(\frac{x}{2} - \frac{N}{4}, \frac{y}{2}$
2. When the pixel $v \in HL_1$ and $v \equiv (x, y)$. In this case the following are the additional 5 neighbours
   - Diagonal Cousin $d_v \in HH_1$ which has coordinates $(x, y + \frac{N}{2})$
   - Horizontal cousin $h_v \in LH_1$ which has coordinates $(x - \frac{N}{2}, y + \frac{N}{2})$
   - Parent $P_v \in LH_2$ which has coordinates $(\frac{x}{2}, \frac{y}{2})$
   - Diagonal Aunt $D_v \in HH_2$ which has coordinates $(\frac{x}{2}, \frac{y}{2} + \frac{N}{4})$
   - Horizontal Aunt $H_v \in LH_2$ which has coordinates $(\frac{x}{2} - \frac{N}{4}, \frac{y}{2} + \frac{N}{4})$
3. When the pixel $d \in HH_1$ and $d \equiv (x, y)$. In this case the following are the additional 5 neighbours
   - Vertical Cousin $v_d \in HL_1$ which has coordinates $(x, y - \frac{N}{2})$
   - Horizontal cousin $h_d \in LH_1$ which has coordinates $(x - \frac{N}{2}, y)$
   - Parent $P_d \in HL_2$ which has coordinates $(\frac{x}{2}, \frac{y}{2})$
   - Vertical Aunt $V_d \in HL_2$ which has coordinates $(\frac{x}{2}, \frac{y}{2} - \frac{N}{4})$
   - Horizontal Aunt $H_d \in LH_2$ which has coordinates $(\frac{x}{2} - \frac{N}{4}, \frac{y}{2})$

Predictions

We have the following three predictions for $\{v, d, h\} \in \{LH_1, HL_1, HH_1\}$

$$
\begin{aligned}
v &= \sum_{i=1}^{4} w_{iv} n_{iv} + w_{5v} d_v + w_{6v} h_v + w_{7v} P_v + w_{8v} D_v + w_{9v} H_v \\
d &= \sum_{i=1}^{4} w_{id} n_{id} + w_{5d} v_d + w_{6d} h_d + w_{7d} P_d + w_{8d} V_d + w_{9d} H_d \\
h &= \sum_{i=1}^{4} w_{ih} n_{ih} + w_{5h} v_h + w_{6h} d_h + w_{7h} P_h + w_{8h} V_h + w_{9h} D_h
\end{aligned}
$$

The above equations can be conviniently written in the Matrix form as follows

$$\vec{V} = Q_v \vec{W}_v$$
$$\vec{D} = Q_d \vec{W}_d$$
$$\vec{H} = Q_h \vec{W}_h$$

Weight and Error Vectors

- W_v, W_d and W_h denote the respective weights of the linear combination.
- We solve these equations in the least square sense

The error vector is defined for each of the three cases as

$$
\begin{aligned}
\vec{E}_v &= \log_2(|\vec{V}|) - \log_2(|Q_v \vec{W}_v|) \\
\vec{E}_d &= \log_2(|\vec{D}|) - \log_2(|Q_d \vec{W}_d|) \\
\vec{E}_h &= \log_2(|\vec{H}|) - \log_2(|Q_h \vec{W}_h|)
\end{aligned}
$$

Features

We have

- $\vec{W}_v$, $\vec{W}_d$, $\vec{W}_h$, $\vec{E}_v$, $\vec{E}_d$ and $\vec{E}_h$.
- $6N$ such vectors for which we calculate skewness which is the measure of the assymetry

The skewness of a vector $\vec{X}$ whose elements x_i have a mean value $\bar{x}$ and variance σ_x^2.

$$S(\vec{X}) = \sum_{i=1}^{N} \frac{(x_i - \bar{x})^3}{\sigma_x^3}$$

- A matrix $I_{14 \times N}$ is constructed by arranging the rows such that $S(\vec{W}_v)$ of each subimage occupy the first row, and so on.
- A similar matrix I_2 is constructed for other image
- Each row of the matrix I_1 and I_2 are passed through ANOVA test for comparison.

Simulation

The threshold in our case is kept 0.8 for ANOVA, 4 cases possible;

- Correct N_c, when the two handwritings (in the images)
  - Match and the result is a *match*
  - Do not match and the result is a *mismatch*
- Miss N_m when the two handwritings match and the result is a *mismatch*
- False Positive N_f when the two handwritings do not match and the result is a *match*

Measures

Define the following to measures

- Precision

$$P = \frac{N_c}{N_c + N_f}$$

- Recall

$$R = \frac{N_c}{N_c + N_m}$$

Results

The simulation had the following experimental results. Let N_T denote total number of comparisons

Table: Correct, Misses and False positives

Measure	Value
N_T	132
N_c	98
N_f	25
N_m	9
P	0.74
R	0.92

References

Some references and a graphic to show you how it's done:

[1] R.W. Buccigrossi and E.P. Simoncelli. âĂIJImage compression via joint statistical characterization in the wavelet domainâĂİ. Image Processing, IEEE Transactions on, 8(12):1688 âĂŞ1701, December 1999.

[2] C. Lytle, B.; Yang. âĂIJDetecting forged handwriting with wavelets and statisticsâĂİ. Rose-Hulman Undergrad. Math. J., 2006.