Content Based Image Copy Detection Based On Sign of Wavelet Coefficients

Fitri Arnia, Agustinus Ifan, Khairul Munadi, Masaaki Fujiyoshi and Hitoshi Kiya

Abstract—Recently, due to affordable price and easy operation of digital camera, massive amount of digital images are available. In addition, digital processing gives users privilege to modify, copy and spread the images over the Internet. In this direction, storage optimization, advertisement tracking and copyright control have become important issues. Content-based image copy detection (CBICD) is one of the schemes designed to solve these issues. The paper presents a CBICD algorithm based on signs of wavelet transform coefficients. Wavelet transform is applied to query and database images, in which the query images have been subjected to several alterations common in CBICD framework such as resizing, contrast and gamma changing and noise addition. Based on signs comparison of query and database images, a similarity measure, which determines whether an image is a copy, is computed. Comparisons were accomplished in level one and two wavelet decomposition, for individual HL, LH, HH sub-band, and combined LL, LH, HL, and HH sub-band. *Recall* and *precision* were used as performance metrics. It turned out that average *recall* and *precision* for HL sub-band at level one was 95% and that at level two was 100%.

***Index Terms*—content-based image copy detection, feature, sign of wavelet coefficient**

I. Introduction

Recently, due to affordable price and easy operation of digital camera, massive amount of digital images are available. In addition, digital processing also gives users privilege to modify, copy and spread the images over the Internet. In this direction, storage optimization, advertisement tracking and copyright control have become important issues. Content-based copy detection (CBCD) is one of the schemes designed to solve these issues. Especially for images, the term CBCD could be conveniently referred to as content-based image copy detection (CBICD).

Some groups consider the CBCD as a special case of image (video) retrieval, which is usually referred to as content-based image (video) retrieval (CBI(V)R). Unfortunately, due to its inherent characteristics of retrieval, in which similarity is frequently derived from semantic point of view, features used in CBI(V)R frameworks usually do not resist common alterations in CBCD such as contrast and gamma changing and noise addition [9,10].

Most of researches in CBCD are addressed to videos [1]-[4], and several others are applied to images [5] – [8]. Work in [5] was among the first attempts in CBICD, which used ordinal measure of DCT coefficients as features. A subsequent research by different authors intended to improve performance of CBICD methods based on ordinal measure was proposed in [6]. Works in [7, 8] are our previous methods in CBICD based on DCT coefficient signs. It was reported that signs of DCT coefficients were efficient feature in terms of size as one image could be represented by 48 bit. Furthermore, the method was also robust against common alterations in CBICD frameworks namely: resizing, contrast and gamma changing and noise addition. It retrieved all copies, neither false negatives nor false positives occurred.

Promised results of our previous research [7,8] motivate us to experiment in the wavelet domain. Therefore in this paper, the use of wavelet coefficient signs as feature for CBICD is proposed. Wavelet transform is applied to query and database images, in which the query images have been subjected to several alterations common in CBICD framework. Based on signs comparison of query and database images, a similarity measure, which determines whether an image is a copy, is computed. Comparisons were accomplished in level one and two wavelet decomposition. In each level, individual HL, LH, HH sub-band, and combined LL, LH, HL, and HH sub-band. *Recall* and *precision* were used as performance metrics. It turned out that average *recall* and *precision* for HL sub-band at level 1 was 95% and that at level 2 was 100%.

II. Background

A. Basic Image Retrieval Diagram for Copy Detection

Basic image retrieval system for copy detection is illustrated in Fig. 1. It can be viewed as consists of two sides, namely user and database sides respectively. At user side, two consecutive processes which include image querying and feature extraction are accomplished. At database side, the same processes take place, the retrieval system take an image from the database and then extract its features. Features of query image and database image are then compared. Decision of whether a user image is a copy, is generally determined by a similarity measure.

B. Review of Discrete Wavelets Transform

Discrete wavelet transform (DWT) is a core processing in JPEG 2000 image compression standard [9]. Wavelets provide multi-resolution capability, good energy compaction and adaptability to human visual system. Wavelet transform represents signals as a superposition of a family of basis functions called wavelets. A family of basis function can be generated by dilating and translating a *mother wavelet* of a particular basis. Basic idea of 1-D dyadic wavelet transform can be seen in Fig.2. Input signal is passed through a low and a high pass filter, and output of each filter is decimated by two. Output of low pass filter $d_{i0}(n)$ are then passed through the same processes, which can be repeated until we obtain

ISBN: 978-602-8944-11-3

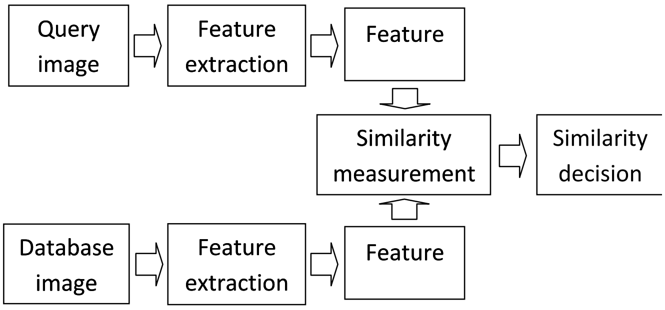
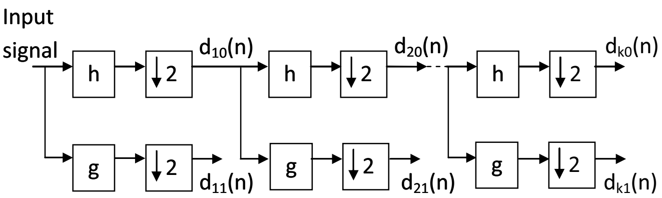
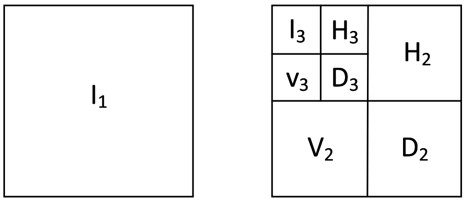


Fig. 1. Basic diagram of image retrieval system for copy detection



- $d_{i0}(n)$: lower band signal at level i
- $d_{i1}(n)$:higher band signal at level i

a. Decomposition



a. Result of two level decomposition applied to an image

Fig. 2. Wavelet transform applied to an image.

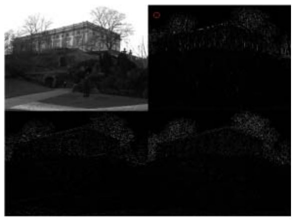
several level decomposition. For images, DWT is generally applied using a separable approach, in which rows and columns are passed to the filter separately. Fig. 3 shows two-level wavelet decompositions of image I_1. In the first level of decomposition, one low pas sub-image (I_2) and three high-pass sub-images (V_2, D_2 and H_2) are created. In the second level decomposition, I_2 is further decomposed into I_3 and V_3, D_3 and H_3. These processes can be repeated until several levels.

C. Similarity Measure of Wavelet Coefficient Signs

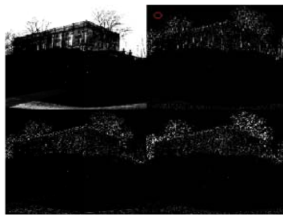
Figure 3 illustrates similarity between two image copies, i.e. (a) original image and (b) its copy with contrast alteration. Figure 3 (c) and (d) are one level DWT decompositions of image (a) and (b) respectively. It can be seen that edges in V_2, D_2 and H_2 sub-band of the image with contrast changing became more visible. Figure 3 (e) and (f) are the 4 x 4 DWT coefficients taken from the top left corner of H_2 of Fig. (c) and

a. Original image

b. Contrast alteration



c. DWT decomposition of a



d. DWT decomposition of b

15,4533	-18,8925	-20,7911	13,1313
-20,6556	12,5306	-6,8667	-6,1637
8,4509	6,6424	-18,0156	19,3130
-12,8612	-5,2693	4,1502	-4,1251

e. DWT coefficient of sub-band LH of c

13,3746	-10,2459	-3,1278	4,1146
1,1829	0,6429	1,6014	-4,4725
-3,8337	-18,4009	-1,2786	-19,7594
7,3077	-1,2194	-7,7106	1,4748

f. DWT coefficient of sub-band LH of c

1	-1	-1	1
-1	1	-1	-1
1	1	-1	1
-1	-1	1	-1

g. Sign of wavelet coefficient of e

1	-1	-1	1
1	1	1	-1
-1	-1	-1	-1
1	-1	-1	1

h. Sign of wavelet coefficient of f

Fig. 3. Process of extracting sign of wavelet coefficients

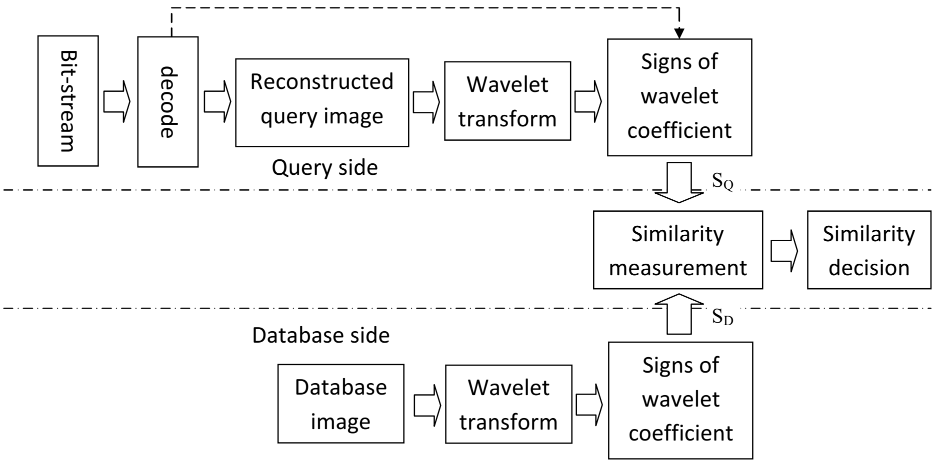


Fig. 4. Diagram block of an image copy detection system based on wavelet coefficient signs

(d) respectively, and Fig. 3 (g) and (h) are their DWT coefficient signs obtained by dividing DWT coefficients in Fig. (e) and (f) with their magnitudes. Similarity in this paper is defined as a similarity between sign of wavelet coefficients between two images under comparison. The same coefficient signs at the same locations will increase the similarity, different coefficient signs at the same locations will decrease the similarity.

III. PROPOSED METHOD

This section firstly describes the model and flow of image copy detection of the proposed method. Then, the algorithm to detect image copies is described.

A. *Diagram Block of Image Copy Detection*

A diagram block of the proposed system for detecting copies from a databases is shown in Fig. 4. The upper part is the query side, the center part shows similarity measurement and similarity decision between query and database images to determine image copies, and the lower part is the database side.

There are two scenarios for detecting image copies, namely on-line and off-line detection. For on-line detection; firstly in the query side, JPEG 2000 code-stream is decoded and coefficient signs are taken (shown by dashed line), the similarity is then measured and copies are detected. For off-line detection, both query and database images undergo: (a) wavelet transform and (b) signs extraction, before a similarity measurement is accomplished. Either the images or the wavelet coefficient signs of images might be saved in the database.

B. *Copy Detection Algorithm*

The similarity $\sigma_{Q,D}$ between wavelet coefficient signs of query (S_Q) and database images (S_D) are measured according to Eq. 1. The numerator in Eq. 1 gives the similarity measure of the two images under comparison. If at the same location *n*, both signs are equal, the similarity of both images increases, i.e.., "1" is added to the similarity measure. Conversely, if at the same location *n*, both signs are different, the similarity of both images decreases, i.e., "-1" is added to the similarity measure. If either or both signs are zero, the similarity value of both images remain the same, i.e., "0" is added to the similarity measure. The denominator of Eq. (1) is the sum of positions in which both coefficients of two images are non-zero. Character "*L*" at the subscript position of the right side of Eq. 1 corresponds to decomposition level, as well as the sub-and selection. For example, *L* could be *1,2,3,…N* level decompositions. At each individual level, one, two, or all sub-bands can be selected. Approximation sub-bands are not able to use as all coefficients are positives.

$$\sigma_{Q,D} = \left(\frac{\sum_{n=0}^{N-1} S_Q(n) S_D(n)}{\sum_{n=0}^{N-1} | S_Q(n) S_D(n) |} \right)_L \quad (1)$$

IV. EXPERIMENTAL RESULTS

A. *Simulation Condition*

A new database is developed based on UCID (Uncompressed Colour Image Database) [10]. The UCID comprises of 1336 of 24 bpp color images with 512×384 pixels (with portrait and landscape orientations). From these images, 10 queries are selected. From each query, 15 attacked-image copies are generated. Totally, there are 1486 images in the developed database. These are summarized in Table I.

Alteration specifications are presented in Table II. There are 4 different sized images, 4 images with contrast and gamma changing, 3 images with noise addition, and 4 images of combined-attack. The entries in the parameter column present the range of variables used in each attack.

TABLE I
IMAGES IN THE DEVELOPED DATABASE

	Basic Database	Developed Database
Label	UCID	UCID + altered images
No. of Image	1336	1334 + 10 x 15 = 1486

TABLE II
IMAGES IN THE DEVELOPED DATABASE

Perubahan	Jumlah	Parameter
Ukuran	4	(0.5), (0.75), (1.5), dan (2.0)
Kontras	2	0.1≤c≤0.9 dan 0.3≤c≤0.7
Gamma	2	γ = 0.5 dan 1.5
Noise	3	Variance = 0.01, 0.05 dan 0.1
Ukuran/Kontras	2	0.7 dan 1.5/0.3≤c≤0.7
Ukuran/Noise	2	0.7 dan 1.5/ 0.1

B. *Performance metrics*

The metrics used to measure detection performances are *recall* and *precision* (R&P). Let n_{correct} and n_{miss} be the number of correct and missed candidates, respectively, among the first *M* retrieval. The *recall* for query image *q* is defined as

$$\text{Re}\,call_q = \frac{n_{correct}}{n_{corret} + n_{miss}} \tag{2}$$

Let n_{wrong} be the number of wrongly retrieved images among the first *M* retrieval. The *precision* for query image *q* is defined as

$$\text{Pr}\,ecision_q = \frac{n_{correct}}{n_{corret} + n_{wrong}} \tag{3}$$

If all *M* attacked/altered versions of query image *q* are retrieved as the first *M* retrieval, the R&P values are equal to “1.” Otherwise, the R&P values will be less than “1.”

C. *Result of the Proposed Method*

Table III and IV show similarity values of the first 16 copies of query UCID1, using wavelet coefficient signs from H_2 and H_3 respectively. As shown in the tables, all 16 altered images including the query itself are detected in the first 16 retrievals.

We simulated using wavelet coefficient signs extracted from one and two wavelet decomposition levels. Individual sub-band namely: D_2, V_2, H_2, D_3, V_3 and H_3 and combined sub-band namely: ($I_2 + D_2 + V_2 +$ H2) and ($I_3 + D_3 + V_3 + H_3$) were used in measuring similarity.

Recall and precision (R&P) at level one, i.e., of using sub-band D_2, V_2, H_2 and combined sub-band ($I_2 + D_2 + V_2 +$ H2) are shown in Tables V, VI, VII and VIII respectively. As can be seen, R&P values are approaching “1”. While the R&P at level two, i.e., of using sub-band D_3, V_3 and H_3 and combined sub-band ($I_3 + D_3 + V_3 + H_3$) reached “1”, except for D_3, which only reached 0.98. These are shown by Tables IX, X, XI, and XII. In general, recall and precision of using coefficient signs from decomposition level two reached the highest value.

TABLE III
SIMILARITY VALUE OF FIRST 15 COPIES USING H_2 SUB-BAND
QUERY: UCID 1

Rank	Image Copy	Similarity Value
1	Query ucid1	1
1	scaling(1,5)ucid887	1
1	scaling(2,0)ucid888	1
2	contrast(0,1-0,9)ucid889	0.7025
3	scaling/contrast (1,5/0,3-0,7) ucid897	0.4732
3	contrast(0,3-0,7)ucid890	0.4732
4	scaling(0.75)ucid886	0.4134
5	gamma(1,5)ucid892	0.3073
6	gamma(0,5)ucid891	0.286
7	noise(0,1)ucid895	0.2234
8	noise(0,01)ucid893	0.2135
9	scaling(0,5)ucid885	0.2069
10	scaling/contrast (0,7/0,3-0,7) ucid896	0.1892
11	noise(0,05)ucid894	0.122
12	scaling/noise(1,5/0,1)ucid899	0.0844
13	scaling/noise(0,7/0,1)ucid898	0.0296

TABLE IV
SIMILARITY VALUE OF FIRST 15 COPIES USING H_3 SUB-BAND
QUERY: UCID 1

Rank	Image Copy	Similarity Value
1	Query ucid1	1
1	scaling(1,5)ucid887	1
1	scaling(2,0)ucid888	1
2	contrast(0,1-0,9)ucid889	0.7017
3	scaling(0.75)ucid886	0.6725
4	scaling/contrast (1,5/0,3-0,7)ucid897	0.4672
4	contrast(0,3-0,7)ucid890	0.4672
5	noise(0,1)ucid895	0.3283
6	gamma(1,5)ucid892	0.3242
7	noise(0,01)ucid893	0.3206
8	gamma(0,5)ucid891	0.3132
9	scaling/contrast (0,7/0,3-0,7)ucid896	0.2936
10	scaling(0,5)ucid885	0.2251
11	noise(0,05)ucid894	0.1978
12	scaling/noise(1,5/0,1)ucid899	0.1655
13	scaling/noise(0,7/0,1)ucid898	0.1058

TABLE V

RECALL DAN *PRECISION* AT SUB-BAND D_3

Query	*Recall*	*Precision*
Ucid1	0,93	0,93
Ucid100	0,93	0,93
Ucid150	0,93	0,93
Ucid200	0,93	0,93
Ucid350	0,93	0,93
Average	0,93	0,93

TABLE VI

RECALL DAN *PRECISION* AT SUB-BAND V_2

Query	*Recall*	*Precision*
Ucid1	0,93	0,93
Ucid100	1	1
Ucid150	1	1
Ucid200	0,93	0,93
Ucid350	0,93	0,93
Average	0,96	0,96

TABLE VII

RECALL DAN *PRECISION* AT SUB-BAND H_2

Query	*Recall*	*Precision*
Ucid1	1	1
Ucid100	0,87	0,87
Ucid150	0,87	0,87
Ucid200	0,93	0,93
Ucid350	1	1
Average	0,93	0,93

TABLE VIII

RECALL DAN *PRECISION* AT SUB-BAND I_2, D_2, V_2, H_2

Query	*Recall*	*Precision*
Ucid1	1	1
Ucid100	0,93	0,93
Ucid150	0,93	0,93
Ucid200	1	1
Ucid350	0,93	0,93
Average	0,96	0,96

TABLE IX

RECALL DAN *PRECISION* AT SUB-BAND D_3

Query	*Recall*	*Precision*
Ucid1	1	1
Ucid100	1	1
Ucid150	1	1
Ucid200	1	1
Ucid350	0,93	0,93
Average	0,98	0,98

TABLE X

RECALL DAN *PRECISION* AT SUB-BAND V_3

Query	*Recall*	*Precision*
Ucid1	1	1
Ucid100	1	1
Ucid150	1	1
Ucid200	1	1
Ucid350	1	1
Average	1	1

TABLE XI

RECALL DAN *PRECISION* AT SUB-BAND H_3

Query	*Recall*	*Precision*
Ucid1	1	1
Ucid100	1	1
Ucid150	1	1
Ucid200	1	1
Ucid350	1	1
Average	1	1

TABLE XII

RECALL DAN *PRECISION* AT SUB-BAND I_3, D_3, V_3, H_3

Query	*Recall*	*Precision*
Ucid1	1	1
Ucid100	1	1
Ucid150	1	1
Ucid200	1	1
Ucid350	1	1
Average	1	1

V. CONCLUSIONS

A new method for image copy detection is proposed in this paper. The method is based on the sign of wavelet coefficients, which act as features. We have shown that image copies can be detected by measuring similarity of their wavelet coefficient signs. It turned out that the detection using wavelet coefficient signs at decomposition level two resulted in higher recall and precisión (R&P) value. Averaged R&P of V_2 was 0.96 and that of V_3 was 1.

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