Exploring Forgeries by Detecting Duplicated Image Regions
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Abstract: With the innovation in technology and availability of imaging tools, it’s not difficult now days to manipulate digital images to hide or add content in images. Image forgery detection is currently one of the hot research fields of image processing. Image forgery detection approach that can adopt two robust features based on discrete wavelet transform (DWT) and principal component analysis (PCA). KPCA (Kernel Principal Component Analysis) extracts non-linear features that are useful than the linear PCA. KPCA represent image data into to high-dimensional space without reducing dimension than the standard PCA. KPCA schemes provide excellent representations of the image data for robust block matching. Experiments with a good number of images shows very promising results, when compared with the conventional DWT, PCA and KPCA based approach.

Keywords: DWT; forgery detection; KPCA; Linear transform; Non-linear transform; PCA

I. Introduction

Digital images are easy to tamper because of the availability of the powerful editing software and sophisticated digital cameras. Some software’s like Photoshop, 3DS Max, photoscape etc. are so sophisticated that it is very hard to differentiate tampered images. From the tabloid magazines to the fashion industry and in mainstream media outlets, scientific journals, political campaigns, courtrooms and the photo hoaxes that land in our e-mail in-boxes, doctored photographs are appearing with a growing frequency and sophistication. As a result, digital evidences have not yet been accepted in real life applications, for example, criminal investigation, medical reporting etc.

Hence the need for some technological solutions to determine if an image has been tampered or not. One of the common cases of tampering an image is the copy-paste tampering. For example, sometimes objects in the real photograph are cut and paste on some part of image. One solution to detect duplicated tampered region from an image is to apply the watermarking to the image. But adding watermarking feature in cameras is an additional cost. Most cameras do not have this feature. So this method cannot be used in general.

The above problem is solve by implementing an algorithm to detect the copy-paste or region-duplication in images using DWT, PCA & extension of PCA is KPCA block based methods are used.

Fig1: Example of copy-move forgery

In the above image, the image on the left side is the real image whereas the one on the right is the forge image of the left one. A portion of the image on the left image is used to cover by the dog in the image. In this way, multiple image objects can be added, hide or deleted from an image.

Exploring forgery detection for digital images is, therefore, an important research area. This system will focus on not only copy move type of image forgery but also for detecting different geometric operation using DWT, PCA and to improve these method of forgery detection extension of PCA i.e KPCA approach is used which provide excellent representations of the image data for robust block matching.

To implement an algorithm for detecting duplicated image region in digital images, different approaches are used in this system for representing the image data which provide robust image feature for detecting duplicated image region.
II. System Architecture

A. Description of the method used

- **DWT**

Wavelet coefficients are extracted from the sub bands after discrete wavelet transform. First applying multi-resolution wavelet decomposition to small fixed-sized image blocks. This transform decomposes an image with an overall scale factor of 4 providing, at each level, one low-resolution sub-image (LL) and three wavelet Coefficients sub-images (HL,LH,HH)[1].

![Fig.2 Processing Steps for Detecting Duplicated Image Region](image)

**A. Description of the method used**

- **PCA**

1. Let \( \tilde{x}_i, i = 1,...,N_b \) denote these blocks in vectorized form

2. Compute the covariance matrix \( C \) as the eigen vectors \( \tilde{e}_j \) of the matrix \( C \), with corresponding eigenvalues as

   \[
   Ce_j = \lambda_j \tilde{e}_j \tag{1}
   \]

3. To define the principal components, where \( j = 1,...,b \) and \( \lambda_1 \geq \lambda_2 \geq \cdots \geq \lambda_b \). The eigenvectors, \( \tilde{e}_j \) form a non linear basis for each image block, \( \tilde{x}_i \)

   \[
   \tilde{x}_i = \sum_{j=1}^{b} a_j \tilde{e}_j \tag{2}
   \]

   Where

   \[
   a_j = \tilde{x}_i^T \tilde{e}_j \tag{3}
   \]

   The dimensionality of this representation can be reduced by simply truncating the sum in Equation (3) to the first \( N_t \) terms.

   Note that the projection onto the first \( N_t \) eigenvectors of the PCA basis gives the best \( N_t \)-dimensional approximation in the least squares sense[13].

These PCA components of each block are used for further processing for detecting duplicated image region.

- **KPCA**

Kernel PCA is a powerful nonlinear feature detector, which has been suggested for various image processing tasks such as compression and denoising requiring. It has been successfully applied to the representation of the natural image. So KPCA is use for detecting tampered regions in the natural images.

Some key points of KPCA

1. KPCA extracts more useful features than the linear PCA[1].
2. Initial mapping to high-dimensional space provides us with smoother dimensionality reduction than standard PCA[1].
3. It does not require nonlinear optimization but just the solution of eigenvalue problem[1]

By using a nonlinear kernel function instead of the standard dot product, we implicitly perform PCA in a possibly high dimensional space which is nonlinearly related to input space, where eigenvectors form a new
nonlinear basis. Implementation of KPCS consists of three different layers, namely input, hidden and output layers. The input layer is made up of source nodes. The input is Test pattern $x_t$, comes from an 16×16 block in the input image. As per image tampering problem, input to a kernel PCA are all pixel intensities corresponding to a data-block[1].

The hidden layer computes a dot product and map input space to the feature space $F$. These two operations are performed in one single step using the kernel function $K(x_t,x_i) = \Phi(x_t)\cdot\Phi(x_i)$[1]. The outputs of the hidden layer are then linearly combined using weights $a_i$, resulting in a nonlinear principal component corresponding to $\Phi[x]$.

**III. Duplicate Detection Algorithm**

1. Provide input image of size $M\times N$. Convert the image to gray scale image
2. Tile the image in $N_b$ overlapping blocks of size $b\times b$. Each block having fixed size $16 \times 16$
   Where $0 \leq i < ( (M-b+1) \times (N-b+1) )$
3. Use 2D wavelet transform in case of DWT transform decomposes an image with an overall scale factor of 4 providing, at each level, one low-resolution sub-image (LL) and three wavelet coefficient sub-images (HL, LH, HH)[1] and Using PCA, compute the new $N_t$-dimensional representation, $\tilde{a}_i$, $i = 1, \ldots, N_b$, of each $b$ pixel image block. The value of $N_t$ is chosen to satisfy: $1 - \epsilon = \frac{\sum_{i=1}^{N_t} \lambda_i}{\sum_{i=1}^{N} \lambda_i}$[13] where $\lambda_i$ are the eigenvalues as computed by the PCA or KPCA.
4. Select Number of Quantization bins $Q$. Construct a data matrix, $M_{data}$, where row-elements contain component-wise quantized features, i.e., $\tilde{a}_i$.
5. Apply lexicographic sorting to the rows of $M_{data}$, matrix to obtain a new matrix $S$. Let $s_i$, be the ith row of $S$, which represents the $i_{th}$ block with its center coordinates $(x_i, y_i)$.
6. Select row threshold parameter $R_{th}$. $R_{th}$ is used to select number of adjacent rows to search. For every pair of rows $s_i$ and $s_j$ from $S$ such that $|i - j| < R_{th}$ place the pair of coordinates $(x_i, y_i)$ and $(x_j, y_j)$ onto a list $F_{in}$.
7. $D_{th}$ is the minimum offset magnitude threshold. Discard all pairs whose offset magnitude, $D_{th} = \left( (x_i - x_j)^2 + (y_i - y_j)^2 \right)^{0.5} < D_{th}$ create a refined list of point pair $F_{out}$ from $F_{in}$.
7. From the remaining pairs of blocks in $F_{out}$ label duplicated region by constructing a zero image of the same size as the original, and coloring all pixels in a duplicated region with a unique grayscale intensity value[1].

**IV. Experiments**

In this system assume that all Test images are taken by digital cameras

Experimental observations showed that KPCA-based feature produces larger average precisions as well as recalls, when compared with the wavelet- or PCA-based feature in case of noisy or compressed images with optimized parameter settings. The reason is due to representing image data using and lexicographic sorting on them[1].

KPCA based feature produces better performance result as compared to the wavelet- and compressed environments.

**A. Results of Duplicate Detection using DWT**

![Fig.5](image)

*(a)Original Image  (b)Input Image  (c)Output Image*

**Result Analysis after applying DWT for test image1**

Image size:157x128  
Number of Blocks:55,460  
Rth:50  
Elapsed time : 1645.879334 seconds.

**B. Results of Duplicate Detection using PCA**
It is clear from the results of the experiment that DWT, PCA and KPCA are block based methods are used for detecting the copy-paste or region-duplication in natural images. KPCA (Kernel Principal Component Analysis) extracts more useful features than the linear PCA and also solves dimensionality reduction problem.

V. Conclusion

The aim behind "Exploring Forgery by Detecting Duplicated Image Region" is implying to detect duplicated image region from the digital image. This system is mainly based on detecting tampered data in form of duplicated image region. It uses various robust block-based feature approaches such as DWT, linear transformer PCA and Non linear transformer Kernel PCA. The results generated after comparing different block-based approaches for detecting duplicated image region, KPCA (Kernel Principal Component Analysis) extracts more useful features than the linear PCA. Initial mapping to high-dimensional space provides us with smoother dimensionality reduction than the standard PCA. KPCA schemes provide excellent representations of the image data for robust block matching. Hence, this system is suitable for applications in which digital evidences in the form of content tampering have not been accepted.

Other heuristics or approaches for estimating the kernel σ parameter may be considered in future. Another challenge is, for detecting forgery in case of simultaneous multiple geometric operations.

VI. References


[12] “Kernel Principal Component Analysis” Bernhard Scholkop, Alexander Smola

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