ObjectMinutiae: Fingerprinting for Object Authentication

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ABSTRACT

In this work, we present *ObjectMinutiae*, which is a framework for authenticating different objects or materials via extracting and matching their fingerprints. Unlike biometrics fingerprinting processes, which use patterns such as ridge ending and bifurcation points as the interest points, our work applies stereo photometric techniques for reconstructing objects' local image regions that contain the surface texture information. The interest points of the recovered image regions can be detected and described by state-of-the-art computer vision algorithms. Together with dimension reduction and hashing techniques, our proposed system is able to perform object verification using compact image features. With neutral and different torturing conditions, preliminary results on multiple types of papers support the use of our framework for practical object authentication tasks.

Categories and Subject Descriptors

H.4 [**Information Systems Applications**]: Miscellaneous

Keywords

object fingerprinting, photometric stereo, keypoints detection, binary descriptor

1. INTRODUCTION

Forgery has been a serious issue in business marketing. Valuable items such as works of art, official documents, and luxury goods often require certain procedures (e.g., watermark, bar code, RFID, etc.) or even expert verification of an item's authenticity. Unfortunately, it is still possible to replicate or even tamper with such authentication processes. Thus, performing material authentication for practical applications can be a very challenging problem.

A desirable solution would be something akin to biometric methods for human identification and verification. Such a process would identify distinctive patterns or key features that could be used to uniquely authenticate an item. Once such patterns are extracted, together with proper hashing or encryption techniques, the resulting features can be compact yet non-replicable, thereby securing the authentication process without requiring additional human verification.

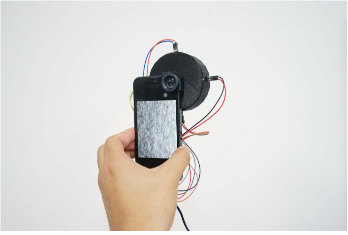

Figure 1: The prototype of our device.

Recently, a number of solutions for object fingerprinting were proposed [2, 3, 5], which generally aim at extracting and encoding the surface texture of objects. In addition, physical properties like textural randomness are further taken into consideration when encoding their extracted features. Nevertheless, the above solutions generally rely on sophisticated machinery settings or require precise alignment. In our work, we present *ObjectMinutiae*, which advances stereo photometric techniques for capturing the local image regions of objects containing surface textural information. By utilizing state-of-the-art computer vision algorithms, ObjectMinutiae produces a set of keypoints with compact features, which enables one to perform image matching for object authentication.

2. OUR METHOD

2.1 Image Sensing

Given an object or a material, we apply the photometric stereo method of [7] to extract the surface textural information of a region of interest (ROI). As illustrated in Figure 1, we currently consider an Apple iPhone5 with Olloclip 21X macro lens and a 3D-printed photometric stereo mask for implementation. For our device, we set up 4 white light LEDs mounted inside the mask (at 0, 90, 180, and 270 degrees) in such a way that each LED can be controlled independently. Compared to recent approaches like [5, 6] which simply capture one image from the ROI, our derived output via stereo photometric techniques would contain detailed information about the surface texture. This allows us to extract unique fingerprints for verification as discussed later.

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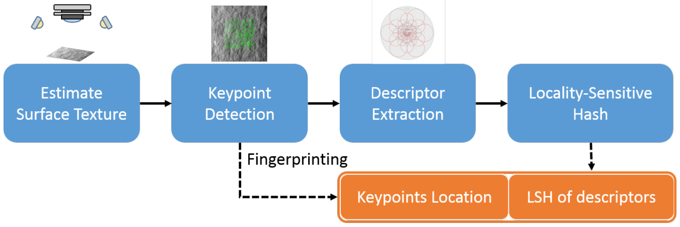


Figure 2: Our proposed framework.

2.2 Fingerprinting

Figure 2 illustrates our framework for object fingerprinting. Once the gradient image of the ROI is derived, the local interest points (i.e., keypoints) are identified and described by FAST [4] and FREAK [1] descriptors, respectively.

In addition, we further apply random projection and locality-sensitive hashing, which allow us to encode the extracted descriptors and reduce their feature dimensions. As a result, only compact information will be required to be stored, processed, and matched for our proposed framework. In our work, we only keep fewer than 300 keypoints for each ROI, while each descriptor requires only 64 bits. Adding the locations of the keypoints results in a fingerprint size for the ROI that is only about 25K bits.

2.3 Authentication Procedure

1. For a ROI, we take 4 images with lighting from 4 different horizontal and vertical directions (i.e., 0, 90, 180, and 270 degrees). Using photometric stereo techniques, we can derive the resulting gradient image describing the surface textural information.

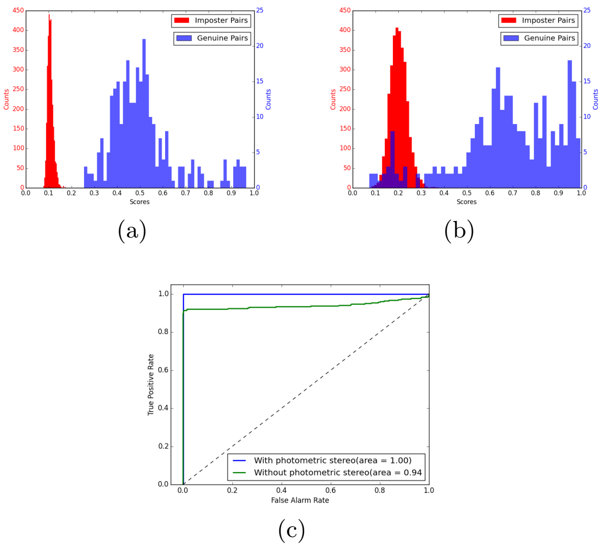
2. We apply FAST keypoint detector to identify the local interest points of the ROI (fewer than 300), while each is described by a FREAK descriptor.

3. For encoding and dimension reduction purposes, we apply random projection on each descriptor with locality-sensitive hashing to reduce each descriptor to a 64-bit binary string. The collection of the binary strings for all descriptors forms as a set of unique minutiae that represents as an object's fingerprint.

4. Once the fingerprints of both gallery and query images are obtained, verification can be performed by matching the corresponding fingerprints.

3. EVALUATION

To evaluate the performance of our verification process, we consider 10 different art paper samples of the same material. For each paper type, we apply two types of tampering processes, rubbing and soaking before acquiring a gradient image, which make the verification task more practical yet difficult. The rubbing process involves vigorously rubbing the paper with an eraser, whereas the soaking process involves soaking the paper in water for an hour.



(a)

(b)

(c)

Figure 3: Matching score distributions of (a) ours and (b) baseline approach. The ROC curve is shown in (c).

For each condition(untampered, rubbed, and soaked) of each paper sample, we capture two gradient images separated by a time interval. Thus, a total of 10 × 3 × 2 = 60 samples would be available for our verification tests. As a result, we have 360 genuine pairs corresponding to different tampering conditions of the same piece of art paper, while 3240 imposter pairs can be obtained. To compare our work with existing methods, we consider the baseline method of [5, 6] which take only 1 photographic (not gradient) image for the ROI, with the use of our descriptors for matching.

Figures 3(a) and 3(b) show the matching score distributions for the genuine and imposter pairs using our and baseline approaches, respectively. It can be seen that, our proposed method was able to distinguish between genuine and imposter pairs, while the standard approach failed to do so. In addition, we plot and compare the ROC curves (i.e., true positive rate (TPR) vs. false alarm rate (FAR)) in Figure 3(c), which also confirms the effectiveness of our approach.

It is worth noting that, our work does not require precise alignment when extracting the object fingerprints. This is due to our use of robust keypoint descriptors. Another advantage is that, with LSH techniques noted in Section 2, the size of the encoded fingerprints is only about 25K bits. As a result, our proposed framework is not only applicable for offline verification tests, but also prevents possible forgery of the object of interest using our encoded fingerprints.

4. REFERENCES

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