Augmenting Real-world Objects by Detecting "Invisible" Visual Markers

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ABSTRACT
This paper describes a vision-based method for detecting and identifying real-world objects in front of the users. The proposed method employs "invisible" visual markers, which are invisible from the users but visible from the *ObjectCam2*, our camera device. The *ObjectCam2* is equipped with IR LEDs around the lens that blink synchronously with the image capture, and the invisible markers consist of lucent and retro-reflective paint. UbiComp applications can be implemented without suffering from the power supply problem nor intrusive visual markers.

ACM Classification: H5.1 [Information interfaces and presentation]: Multimedia Information Systems. - Artificial, augmented, and virtual realities.

General terms: Design, Human Factors.

Keywords: Real-world Computing, Retro-reflective Marker.

INTRODUCTION
This paper proposes a new method for identifying objects in the real-world by detecting "invisible" visual markers by the *ObjectCam2* [8], a kind of active IR camera. It is required to identify real-world objects to realize most UbiComp applications and also to detect their posture to realize augmented reality (AR) applications. By identifying target objects in front of the user, for instance, such systems can augment the objects with virtual annotations when they simply take a look at or come nearby the objects, i.e., they can be provided with the information associated with the objects. Typical object identification techniques in these fields employ either of radio tags[3], active optical tags[4], visual markers[2], or vision-based object recognition[6, 7]. Although tag-based approaches are more reliable for identifying objects than other approaches, the active tags which require power supply cannot be embedded in every object.

Although recognition/identification results from vision-based methods tend to be more ambiguous than those of tag-based approaches, vision-based methods have advantage in simplicity of their device configuration. Especially use of visual markers increases robustness and reduces computation time. Typical marker-based methods like ARToolkit[2] employ square black and white images with a simple pattern inside as a marker and a unique pattern represents the ID of the object/region where the marker is placed. One of the biggest problems for introducing visual markers into daily life is their intrusiveness.

Nakazato et al. proposed a localization method for wearable AR systems that employs invisible markers consisting of translucent retro-reflectors[5]. In addition to the ordinary color camera for scene capturing it employs an IR camera and blinking IR LEDs for localization. Invisible markers are set on the ceilings or walls and the IR camera captures the reflection of the IR LEDs. Hanhoon et al. proposed a method for AR applications that detects invisible markers drawn with IR Pen[1]. Their camera system is similar to our older version of *ObjectCam* [7], i.e., a color camera for scene capturing and an IR camera for tracking are positioned in each side of a cold beam splitter. Although these approaches are free from visual intrusiveness, both employ two cameras that increase size, weight, and computational requirements. Although translucent retro-reflectors can be placed to materials with less texture such as ceilings used in [5], translucent markers on textured objects are also intrusive.

Our proposed method employs the single color camera, called *ObjectCam2*, which has IR LEDs blinking synchronously with the image capture and can capture both the real scene and the reflection of the IR illumination for identifying the invisible markers consist of lucent and retro-reflective paint. Our method has less substance limitation than the method using IR Pen, because each marker is implemented as a directly sprayed pattern on to the surface of an object.

OBJECT IDENTIFICATION AND APPLICATION
ObjectCam2
The *ObjectCam2* was originally developed as a wearable camera for detecting handheld objects [8]. It is a kind of active IR camera with an IR LED array in its front and is equipped with the CMOS image sensor whose frame rate is 90fps. The image sensor has no IR cutoff filter so that the *ObjectCam2* can capture an image that has luminance within both visible and IR light range. It controls blinking in the IR

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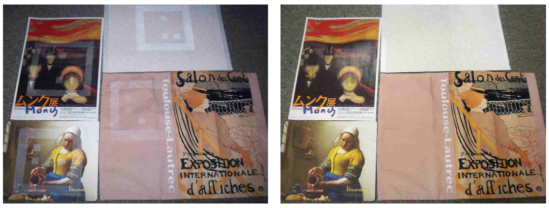

(a) LEDs On (b) LEDs Off

Figure 1: Real-world objects annotated by invisible markers

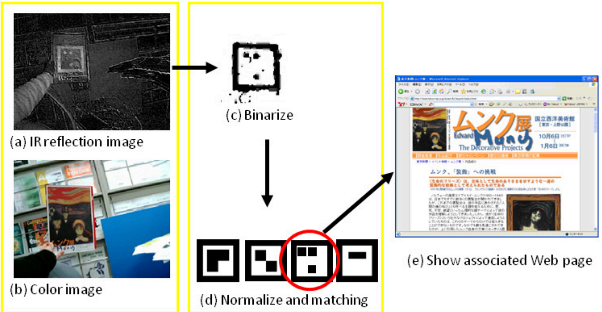

Figure 2: System Diagram

LED array synchronously to the image capture, and captures both two color images with reflected active IR light (Figure 1(a)) and a color image without the lights (Figure 1(b)) in 1/30 sec. By subtracting image (b) from image (a) on the FPGA circuit implemented in the *ObjectCam2*, it can generate both the IR reflection image and the color image of the scene , i.e., image (b), at 30fps.

Invisible Marker

The *ObjectCam2* captures the reflection image of the IR illuminant at 30fps as described before. Because the retro-reflector reflects a light toward a light source, its reflection of IR LEDs which are set around the lens are clearly captured by the *ObjectCam2*. Our invisible markers consist of lucent and retro-reflective paint which contains retro-reflective glass beads in oil-based solvent. Because a marker pattern is directly sprayed onto the surface of a target object, it can be applied to almost any substances. Figure 1 shows real-world objects of which invisible markers are set on the surface. Figure 1(a) is the image captured when the lights are on and (b) is off. The materials are a booklet made of coated paper (upper left), a wallpaper (upper right), a nylon top mouse pad (lower left), and a cotton luncheon mat (lower right). The marker patterns can be extracted by subtracting image (b) from image (a).

Marker Detection and Identification

Figure 2 shows the diagram of our prototype application that detects target objects in a scene and shows the web page associated with the object whose marker occupies the largest region in the scene. Figure 2(b) shows the scene which contains the same booklet as upper left of Figure 1 with complex background. Figure 2(a) shows the IR reflection image of the scene. The system detects invisible markers and identifies them from image (a) by the following process:

1. binarizes the reflection image and eliminates noise by recursively applying erosion and dilation transform,
2. detects marker candidate region(s) by finding closing contours and approximating each of them using Douglas-Peucker polyline simplification algorithm, and selects the largest candidate region,
3. normalizes the size of the region image (Figure 2(c)), and
4. matches the region image with marker templates and identifies the marker.

When a marker is detected and is successfully identified, the system passes its ID to the application.

Application

Our prototype application shows the web page associated with the identified real-world object as described before. In Figure 2, for instance, the object is successfully identified as the booklet of Munch exhibition held in a Japanese museum so that the application shows the exhibition web page.

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