Using a Dual-Camera Smartphone to Recognize Imperceptible 2D Barcodes Embedded in Videos

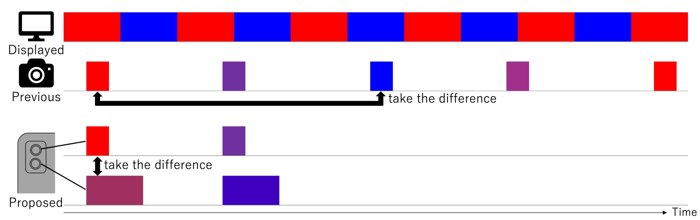
Yuki Kakui
The University of Tokyo
Tokyo, Japan
ykakui@nae-lab.org

Kota Araki
The University of Tokyo
Tokyo, Japan
araki@nae-lab.org

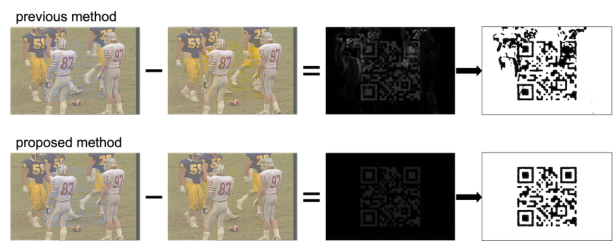
Changyo Han
The University of Tokyo
Tokyo, Japan
hanc@nae-lab.org

Shogo Fukushima
Kyushu University
Fukuoka, Japan
shogo@ait.kyushu-u.ac.jp

Takeshi Naemura
The University of Tokyo
Tokyo, Japan
naemura@nae-lab.org



(a) Capture method. The proposed method uses a dual-camera smartphone for simultaneously capturing two images with different exposure times.



(b) Decoding result of the video clip, "football" [7] obtained by the simulation experiment. While the QR code cannot be read in the previous method, it can be read in the proposed method since the artifacts caused by the interframe differences are reduced.

Figure 1: Comparison of the previous method [1] and the proposed method

ABSTRACT

Invisible screen-camera communication is promising in that it does not interfere with the video viewing experience. In the imperceptible color vibration method, which displays two colors of the same luminance alternately at high speed for each pixel, embedded information is decoded by taking the difference between distant frames on the time axis. Therefore, the interframe differences of the original video contents affect the decoding performance. In this study, we propose a decoding method which utilizes simultaneously captured images using a dual-camera smartphone with different exposure times. This allows taking the color difference between the frames that are close to each other on the time axis. The feasibility of this approach is demonstrated through several application examples.

CCS CONCEPTS

• **Human-centered computing** → **Ubiquitous and mobile computing systems and tools**.

KEYWORDS

screen–camera communication, ubiquitous computing

ACM Reference Format:
Yuki Kakui, Kota Araki, Changyo Han, Shogo Fukushima, and Takeshi Naemura. 2022. Using a Dual-Camera Smartphone to Recognize Imperceptible 2D Barcodes Embedded in Videos. In *The Adjunct Publication of the 35th Annual ACM Symposium on User Interface Software and Technology (UIST '22 Adjunct), October 29-November 2, 2022, Bend, OR, USA.* ACM, New York, NY, USA, 3 pages. https://doi.org/10.1145/3526114.3558672

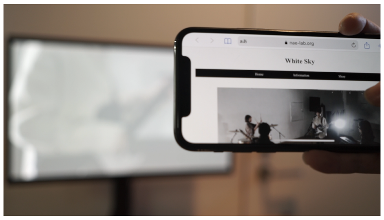
1 INTRODUCTION

Visible 2D barcodes such as QR codes [2] are widely used for screen-camera communication. However, they are obtrusive and can interfere with the video viewing experience. Therefore, extensive research has been conducted on invisible screen-camera communication. Some approaches involve making small changes in pixel values that are imperceptible to human eyes [3, 5]. However, these approaches cannot achieve high throughput. Meanwhile, approaches that utilize complementary brightness changes that exceed the critical flicker frequency (CFF) require a display with a refresh rate of 120 Hz as the CFF of brightness is approximately 60 Hz [6, 8, 9]. Some approaches, such as imperceptible color vibration [1], leverage the chromatic CFF, which is approximately 25 Hz [4].

In the imperceptible color vibration method, data is encoded as the color modulation in the XZ plane of the XYZ color space and two frames are displayed at 60 Hz. During the decoding process, images are captured every 1/24 s and the absolute difference is

UIST '22 Adjunct, October 29-November 2, 2022, Bend, OR, USA

ACM ISBN 978-1-4503-9321-8/22/10.
https://doi.org/10.1145/3526114.3558672



(a) Hyperlink to the artist's website in music video

(b) Instant subtitles on smartphone screen (left: English, right: Japanese)

(c) Landmark information spatially embedded in the sightseeing video.

Figure 2: Application examples of extracting information embedded in videos

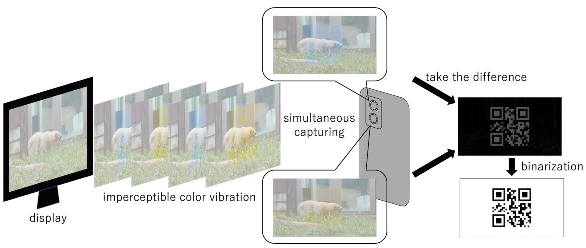


Figure 3: Simultaneous capturing of two images with different modulation values. The color modulation intensity is emphasized more than the actual value for visualization.

taken between the current frame and the second previous frame, as illustrated in Figure 1 (a). Therefore, if the content shown on a display has intense movements, the decoded data is impaired by interframe differences in the original video content, as shown in Figure 1 (b).

In this study, we present a method which can simultaneously capture images of different modulation values with two cameras on a smartphone; this method reduces the artifacts caused by temporal changes in the original video content.

2 METHOD

In the proposed method, images are captured simultaneously using two cameras on a smartphone with different exposure times, as shown in Figure 1 (a). By changing the exposure times, two images with different amounts of color modulation are obtained, then the difference between these images is taken as illustrated in Figure 3. These images are closer on the time axis compared to the previous method. Therefore, the decoded 2D barcode is considered to be less affected by the temporal changes of original video contents.

The proposed method consists of the following four steps: 1) color correction, 2) simultaneous capturing of the images, 3) angle of view correction, and 4) decoding. We used an iPhone 11 Pro to implement this method. First, color correction is performed between the two cameras beforehand using the functions provided within the Apple framework. Two images are then captured simultaneously with different exposure times. Subsequently, angle of view correction is performed between the two cameras. Feature points are extracted using Oriented FAST and Rotated BRIEF (ORB) and are matched. One image is then warped using homography to match the other image. Finally, decoding is performed by obtaining the absolute difference of the components apart from the luminance between two images. Subsequently, we adopt blur filtering and binarize the image to detect the 2D barcode (QR code).

We conducted the simulation experiment on a PC to show the effect of the proposed method, since the start time of capturing corresponding to display frame switching cannot be adjusted when using the actual devices. In the experiment, we simulated 2) simultaneous capturing of the images and 4) decoding, not taking 1) color correction, 3) angle of view correction and noise into consideration. As shown in Figure 1 (b), the proposed method could recover 2D barcodes more robustly than the previous method especially in videos of intense movements.

For both simulation and actual device implementation, we used exposure times of 1/250 s and 1/50 s respectively for each camera in the simultaneous capturing process.

3 APPLICATIONS

The proposed method can be used to decode imperceptible 2D barcodes in video contents. For example, additional information can be added in advertisements such as music videos, as shown in Figure 2 (a). Users can immediately access the website of the artist to check their products by holding a smartphone over the display. Additionally, time-varying information can be embedded based on the original video content. Subtitles can be embedded temporally and users can get the explanation in their major languages as shown in Figure 2 (b). In the sightseeing video, users can get information on sightseeing spots by pointing a smartphone toward those spots, as shown in Figure 2 (c).

4 CONCLUSION AND FUTURE WORK

In this study, we proposed a method to detect invisible 2D barcodes embedded in videos by simultaneously capturing images using dual-camera smartphones. This is achieved by obtaining the difference between the frames that are close to each other on the time axis. The approach presents considerable potential for a wide range of applications. A limitation of our method is that the color difference obtained by simultaneously captured images can be small when capture start time is not desirable and is insufficient to recover 2D barcodes. In the future, to improve the robustness of recognition, we will consider the time interval of image capture to avoid consecutive decoding failures.

REFERENCES

[1] Satoshi Abe, Takefumi Hiraki, Shogo Fukushima, and Takeshi Naemura. 2020. Imperceptible Color Vibration for Screen-Camera Communication via 2D Binary Pattern. *ITE Transactions on Media Technology and Applications* 8, 3 (2020), 170–185.

[2] International Organization for Standardization. 2015. Information technology — Automatic identification and data capture techniques — QR Code bar code symbology specification. Retrieved July 9, 2022 from https://www.iso.org/standard/62021.html

[3] Mostafa Izz, Zhongyuan Li, Hongbo Liu, Yingying Chen, and Feng Li. 2016. Uber-in-light: Unobtrusive visible light communication leveraging complementary color channel. In *IEEE INFOCOM 2016 - The 35th Annual IEEE International Conference on Computer Communications*. IEEE, San Francisco, CA, USA, 1–9. https://doi.org/10.1109/INFOCOM.2016.7524513

[4] Yi Jiang, Ke Zhou, and Sheng He. 2007. Human visual cortex responds to invisible chromatic flicker. *Nature neuroscience* 10, 5 (2007), 657–662.

[5] Tianxing Li, Chuankai An, Andrew Campbell, and Xia Zhou. 2014. HiLight: Hiding Bits in Pixel Translucency Changes. In *Proceedings of the 1st ACM MobiCom Workshop on Visible Light Communication Systems* (Maui, Hawaii, USA) *(VLCS '14)*. Association for Computing Machinery, New York, NY, USA, 45–50. https://doi.org/10.1145/2643164.2643171

[6] Viet Nguyen, Yaqin Tang, Ashwin Ashok, Marco Gruteser, Kristin Dana, Wenjun Hu, Eric Wengrowski, and Narayan Mandayam. 2016. High-rate flicker-free screen-camera communication with spatially adaptive embedding. In *IEEE INFOCOM 2016 - The 35th Annual IEEE International Conference on Computer Communications*. IEEE, San Francisco, CA, USA, 1–9. https://doi.org/10.1109/INFOCOM.2016.7524512

[7] University of Mannheim. 2011. Test Sequences. Retrieved July 17, 2022 from https://pi4.informatik.uni-mannheim.de/~kiess/test_sequences/download/

[8] Anran Wang, Zhuoran Li, Chunyi Peng, Guobin Shen, Gan Fang, and Bing Zeng. 2015. InFrame++: Achieve Simultaneous Screen-Human Viewing and Hidden Screen-Camera Communication. In *Proceedings of the 13th Annual International Conference on Mobile Systems, Applications, and Services* (Florence, Italy) *(MobiSys '15)*. Association for Computing Machinery, New York, NY, USA, 181–195. https://doi.org/10.1145/2742647.2742652

[9] Kai Zhang, Yi Zhao, Chenshu Wu, Chaofan Yang, Kehong Huang, Chunyi Peng, Yunhao Liu, and Zheng Yang. 2019. Chromacode: A fully imperceptible screen-camera communication system. *IEEE Transactions on Mobile Computing* 20, 3 (2019), 861–876.