

Watermark Embedding and Extraction Scheme Design by Two-stage Optimization for Illegal Replication Detection of Two-dimensional Barcodes

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Abstract: Recently, two-dimensional (2D) barcodes displayed on mobile phones are becoming used for authentication such as airplane boarding pass and online payment. Digital watermarking is promising technology to detect illegal replication or fabrication of such 2D codes. However, due to geometric distortions and/or interferences between patterns of camera sensors and screen pixels, watermark may not be sufficiently extracted from subbands which are used when embedding the watermark. This paper proposes a two-stage optimization method for watermark embedding and extracting scheme design. The proposed method discriminates frequency subbands between for embedding and extraction, whereas general watermarking schemes extract the watermark from the same subbands as while embedding. To evaluate actual image deterioration by digital-analogue conversion with mobile phone screen and camera, the proposed method uses actual mobile phones to obtain real images of valid and replicated 2D codes. Experimental result have shown that the proposed two-stage optimization of watermark embedding and extracting schemes improved watermark performance for 2D code replication detection.

1 INTRODUCTION

Barcodes are used for object recognition and identification in various areas, such as production, logistics, and commerce. Quick Response (QR) codes, a kind of two-dimensional barcode (2D code) investigated by Denso Wave Inc., are currently used in Japan as a shorthand method of accessing (an "analogue shortcut"), for example a URL, an e-mail address, a phone number, and so on. Most Japanese mobile phones are equipped with a camera and QR code decoder. By holding a mobile phone over QR codes printed on papers, billboards, television screens, or digital signage monitors, users can decode the QR code and browse Web sites or send e-mails without typing URLs or e-mail addresses on their mobile phones.

In recent years, QR codes (and other 2D codes) are becoming used for authentication such as airplane boarding passes and online payments. In particular, over the past few years, 2D codes displayed on mobile phone screens have become increasingly common as a paperless verification. In mobile phone apps such as

"Mobile AMC Application" by All Nippon Airways and "Passbook" by Apple, the barcode is displayed on the phone screen and a passenger holds his/her mobile phone over a barcode reader. Such paperless tickets and coupons promote reduction of environmental impacts. Indeed, in 2007, the International Air Transport Association standardized an automatic check-in system using a 2D code to reduce expenses and industrial waste by replacing boarding passes using magnetic tape with mobile phones.

However, illegal replication or fabrication of 2D codes has not been considered to date. Fig. 1 shows an example replication of a 2D code displayed on a mobile phone screen by other mobile phone's camera. The importance of technologies for detecting counterfeit and copied 2D code is rising, not only to avoid financial losses but also to enhance the security and safety of social hubs such as airports and train stations. Although woven patterns are widely used in paper documents to detect a copy, it is difficult to distinguish between valid and counterfeit 2D codes displayed on mobile phone screens.

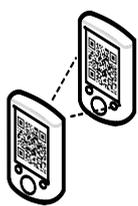
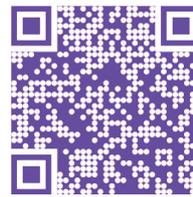


Figure 1: Illegal replication using mobile phones.



(a) Cover 2D code image (b) Watermarked image

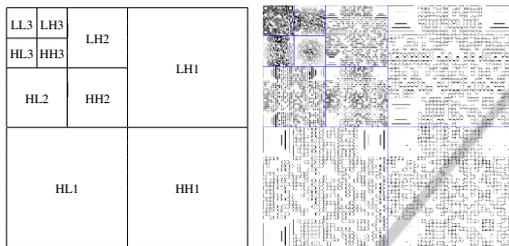
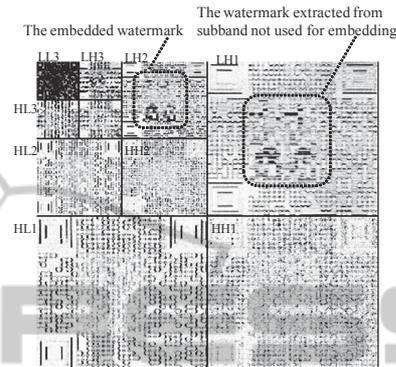


Figure 2: DWT subbands and example DWT output.



(c) DWT output

Figure 3: Watermark extraction example in which watermark is extracted from not only subband used for embedding the watermark (LH2) but also other subband (LH1).

Recently, digital watermarking has been widely used for copyright protection and the detection of image modification and attacks. Digital watermarking techniques can be divided into robust and fragile watermarking. For instance, robust watermarking is used to protect copyright information even when a watermarked image is replicated or modified, while a fragile watermark detects modification and tampering attacks by being destroyed by them. Semi-fragile watermarking is used to detect modifications and attacks on printed images, whereas fragile watermarking is used to detect modifications and attacks by digital image processing. Compared to robust and fragile watermarking, little attention has been paid to semi-fragile watermarking (Rey and Dugelay, 2002; Song et al., 2001).

Ono et al. proposed a semi-fragile watermarking scheme for color 2D barcodes that detects illegal replication (Ono et al., 2011; Ono et al., 2013; Ono et al., 2014). This method uses Discrete Wavelet Transform (DWT) (Kundur and Hatzinakos, 1997; Kundur and Hatzinakos, 1998), and embeds a watermark image as a high-frequency component in the oblique direction. Fig. 2 shows frequency subbands and example output images of three-level DWT; HL, LH and HH denotes high frequency coefficients (subbands) in horizontal, vertical and diagonal directions, respectively, and LL is low image subbands. The digit of subband name corresponds to the DWT level.

Illegal replication of printed images with the above watermark by photocopiers destroys the watermark because the photocopiers express colors with dotted or diagonal striped patterns of primary colors, which involve diagonal high frequency component. Although the above semi-fragile watermarking

method produces copy-detectable 2D barcodes, the method is basically designed for barcodes on print media.

Then, Ono et al. applied this scheme to 2D code displayed on mobile phone screens, which was achieved by subband selection and watermarking strength optimization (Ono et al., 2014). Various types of flat display panels likely require different watermarking schemes. Thus, to obtain actual valid and counterfeit 2D code images, the solutions of this method are evaluated on actual mobile phones. In addition, a flexible watermark that can be used on various mobile phones is achieved by formulating the watermark design as a multi-objective optimization problem. Implementing multi-objective optimization with real mobile phones is an effective design approach for both semi-fragile as well as inconspicuous robust watermarks.

However, due to slight geometric distortions and frequency gaps between screen pixels and camera imaging sensors, watermark may not be sufficiently extracted from subbands which are used when embedding the watermark. Fig. 3 shows an example of watermark extraction from a camera-captured image. In this example, although the watermark is embedded into LH2, the watermark is extracted from LH1 in addition to LH2. The above-described shows that robust watermark extraction should be performed by referring some additional subbands. However, the pre-

vious method (Ono et al., 2014) embeds watermark into multiple subbands, e.g., HL1, HL2, and HH2 are used at darker regions of a cover image. Therefore, it is difficult to determine an appropriate subband set for extracting the watermark when it is embedded to multiple subbands.

This paper proposes a method for simultaneous optimization of watermark embedding and extracting schemes. The proposed method discriminates frequency subbands and strength between when embedding and extraction, whereas general watermarking schemes extract the watermark from the same subbands as while embedding. Although it is expected that simultaneous optimization for watermark embedding and extraction schemes allows to achieve appropriate semi-fragile watermarking, the optimization problem scale becomes larger. Therefore, the proposed method performs a two-stage optimization, in which watermarking subbands and strength are optimized first without distinction between during embedding and extracting, and then subbands and their strength peculiar to both embedding and extraction are discriminated and optimized simultaneously. To evaluate actual image deterioration by digital-analogue conversion with mobile phone screen and camera, the proposed method uses actual mobile phones to obtain valid and replicated 2D code images.

Experimental results have shown that the simultaneous optimization of watermark embedding and extracting schemes improved watermark performance for replication detection.

2 RELATED WORK

Many researchers of digital image copyright protection have adopted optimization techniques in their robust watermark designs. For example, Vahedi et al. proposed a watermarking approach for color images (Vahedi et al., 2012) using discrete wavelet transform (DWT) analysis (Kundur and Hatzinakos, 1997; Kundur and Hatzinakos, 1998). This method optimizes the watermark embed levels for subbands, thereby improving watermark robustness to various intentional and unintentional attacks while ensuring a high level of perceptual quality. The objective function is the linear sum of three objectives: visual quality, robustness, and amount of embedded information. Mingzhi and Yan (Mingzhi et al., 2013) proposed a combined DWT and Discrete Cosine Transform (DCT) scheme (Rao and Yip, 1990), based on a watermarking scheme optimized by genetic algorithm (GA) (Goldberg, 1989). In this method, fitness calculations are performed on images corrupted by attacks,

such as JPEG compression, Gaussian filtering, image sharpening, and cropping. In the method of Chu et al., DWT is used to select appropriate zerotrees that preserve both the cover image quality and the robust embedded watermark (Chu et al., 2008). Huang et al. optimized both the watermarked image quality and the robustness of the extracted watermarks by tabu search (TS). This approach overcomes channel impairments while ensuring copyright and ownership protection (Huang et al., 2011). Another approach is singular value decomposition and lifting wavelet decomposition (Loukhaoukha et al., 2014). In this method, the subjective quality and wavelet analyses are performed by a just noticeable distortion (JND) model and Sym-4, respectively.

All the above methods attempt to resist deliberate attacks by applying benchmarks to watermarked digital media, and the solutions are evaluated by simulation.

3 THE PROPOSED METHOD

3.1 Overview

This paper proposes a design method for watermark embedding and extracting scheme in order to distinguish genuine 2D codes and their replica. The target 2D codes are displayed on mobile phone screens, and we assume that replication is performed by capturing the genuine 2D code displayed on a mobile phone with another mobile phone camera as shown in Fig. 1¹. Semi-fragile watermark is necessary to discriminate between them; the watermark is extracted only from genuine 2D codes, and the replication, which is digital-analogue conversion (Ho et al., 2003), destroys the watermark.

The basic idea of the proposed method is as follows:

1. The proposed method uses 3-level 2D Haar DWT based watermark.
2. Different frequency subband sets are allowed to be used during watermark embedding and extracting.
3. Real-coded GA (Eshelman and Schaffer, 1993) is used as an optimizer.
4. Two-stage optimization is adopted to find a good solution of the target high-dimension problem.
5. Actual mobile phones are used to evaluate semi-fragility of designed watermark schemes.

¹Digital copying of 2D code images can be prevented by other digital technologies.

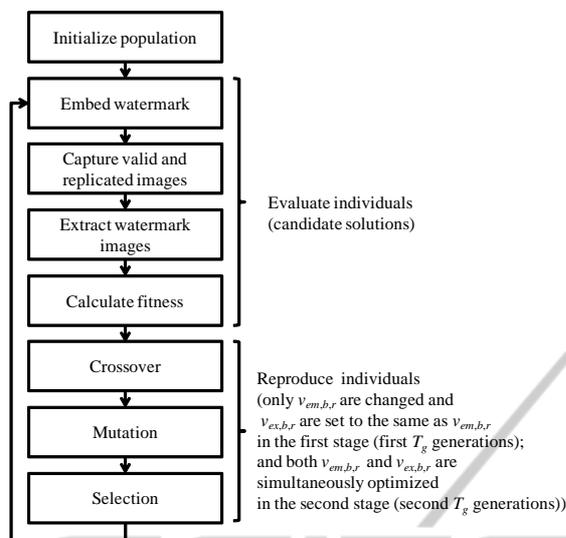


Figure 4: Process flow of the proposed method.

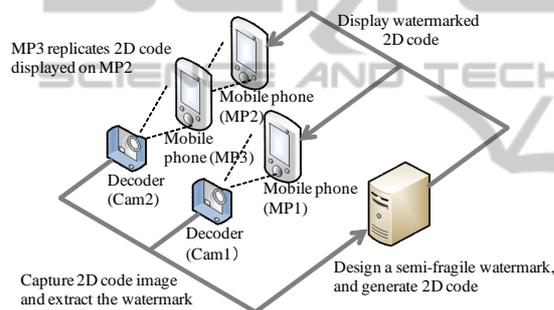


Figure 5: Proposed watermarking evaluation system structure (with one mobile phone model).

The proposed method is essentially based on the previous work (Ono et al., 2014), and the difference between the previous work and the proposed method is 1., 2., and 4. in the above list. The proposed method realizes the semi-fragility by subband selection and strength adjustment; they are distinguished and different subbands and strength levels are used between when embedding and extracting, whereas the previous work does not discriminate between them. To promote the effectiveness of distinct schemes, 3-level DWT is used in this paper. On the other hand, the distinct scheme design and 3-level DWT make the problem much larger than the previous work. Therefore, the proposed method performs subband selection and strength adjustment by two-stage optimization to find a good solution within little search cost.

3.2 Process Flow

Fig. 4 shows the process flow of the proposed method for watermarking scheme design. The proposed

method iterates solution candidates (individuals) generation and their evaluation according to general process flow of GA.

Unlike general non-linear programming algorithms, GA is a multi-point search method in which many individuals simultaneously look for a global optimum and interact with each other. The initial population of individuals are generated randomly, and population recombination is performed by genetic operators; selection, mutation and crossover.

The proposed method evaluates individuals with actual mobile phones. Fig. 5 shows the system for individual evaluation. A watermarked image, which is a phenotype of individual, is generated according to chromosome of the individual. The above watermarked image, which is regarded as a valid code, is displayed on mobile phone MP₁ and captured by camera Cam₁.

After capturing the valid 2D code image, the valid code is also displayed on MP₂. Then, replication is performed; the above 2D code displayed on MP₂ is captured by a camera of MP₃. The replicated 2D code image is shown on MP₃ screen, and it is captured by camera Cam₂. To avoid the influence of image processing and compression of file format, MP₃ directly shows the captured image without recording. The valid watermarking extraction process performed by MP₁ and Cam₁ evaluates the robustness of the watermark sufficiently to overcome the noise caused by digital-analogue conversions via the mobile phone screen and the camera. Moreover, the replication process by MP₂, MP₃, and Cam₂ evaluates the fragility of the watermark sufficiently to be destroyed by two digital-analogue conversions between MP₃ and MP₂ and between MP₂ and Cam₂.

3.3 Optimization

3.3.1 Design Variables

Simultaneous optimization of watermark embedding and extracting scheme that is a target task of the proposed method involves both frequency band selection and strength adjustment. Adequate subband selection and embedding/extracting strength adjustment are indispensable in semi-fragile watermarking. Therefore, design variables are designed to cope with both subband selection and strength adjustment. Variable $v_{p,b,r}$ is a real value and ranges from 0 to 1, where p denotes the process, embedding em or extracting ex , b denotes a subband, and r denotes cover 2D code region to be embedded. The subband set used in this study comprises vertical direction subbands LH1, LH2, LH3, horizontal direction subbands HL1, HL2,

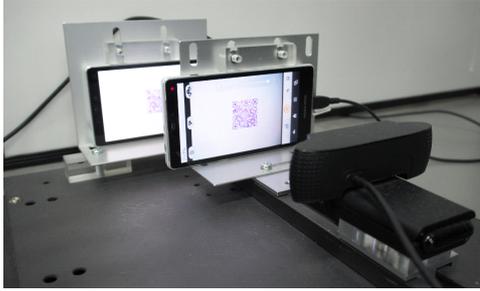


Figure 6: Implemented evaluation system.

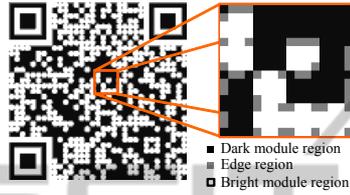


Figure 7: Three regions of 2D codes: bright modules, dark modules, and edge regions.

HL3, diagonal direction subbands HH1, HH2, HH3, and low frequency subband LL3. In our method, the image region is divided into three regions according to the brightness of cover 2D code image; brighter module region b , darker module region d , and edge (intermediate bright) region e .

If $v_{p,b,r}$ is higher than 0.5, then subband b of image region r is used to embed or extract the watermark. The embedding/extracting strength is determined by the following equation;

$$L_{p,b,r} = \begin{cases} 2 \times (v_{p,b,r} - 0.5) \times L_{max} & \text{if } v_{p,b,r} > 0.5 \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

If $v_{p,b,r}$ is below 0.5, subband b of image region r is not used for embed/extracting.

The target problem has totally 60 dimensions, which is considerably larger problem than the problem with 21 dimensions in the previous work (Ono et al., 2014).

3.3.2 Objective Function

The proposed method designs semi-fragile watermark; the desirable semi-fragile watermark is extracted only from valid 2D code and not from replicated one. Therefore, semi-fragileness is represented by the watermark extraction accuracy difference between valid and replicated 2D codes. On the other hand, there is a constraint that the cover 2D code of the valid image must be decoded by a general 2D code decoder even though the watermark is embedded. Besides, it does not matter whether the cover 2D code of

Table 1: Parameter configuration.

Parameters	values
Population size	300
T_g	200 generations
Termination condition	200 + 200 generations
Crossover	blend crossover (BLX- α) (Eshelman and Schaffer, 1993) $\alpha = 0.5$
Mutation	uniform random
Mutation rate	0.05

the replicated image can be decoded by the general decode or not.

According to the above consideration, objective function $f(I)$ of individual (candidate solution) I is defined as follows:

$$f(I) = \text{BCR}(W, W^{valid}) - \text{BCR}(W, W^{replicated}) - P(Y^{valid}) \quad (2)$$

where W denotes digital watermark image, and W^{valid} and $W^{replicated}$ are extracted watermark images from valid and replicated 2D code images, respectively. BCR denotes the pixel-wise coincidence ratio between two images. $P(Y^{valid})$ is a penalty function which is calculated based on error correction usage ratio of the captured cover 2D code Y^{valid} .

3.4 Two-stage Optimization

As described in Sec. 3.3.1, the target problem involves 60 design variables, in which it is not easy to find the global optimum. In addition, the subbands which are used for embedding watermark are essentially used when also extracting. Therefore, the proposed method utilizes two-stage optimization. In the first stage, the embedding and extracting strength $v_{em,b,r}$ and $v_{ex,b,r}$ are optimized without any distinction as $v_{em,b,r} = v_{ex,b,r}$ to reduce the search space. Then, in the second stage, all 60 variables are discriminated and simultaneously optimized. The first stage takes first T_g generations of the search, and then the second stage does during T_g generations. The best solution of the first stage is used as part of initial solutions of the second stage, resulting in an improvement of both accuracy and search efficiency.

4 EVALUATION

4.1 Experimental Setup

To verify the effectiveness of our method, experiments were conducted with actual mobile phones (SHARP ISW16SH equipped with 4.6 inch 720 ×

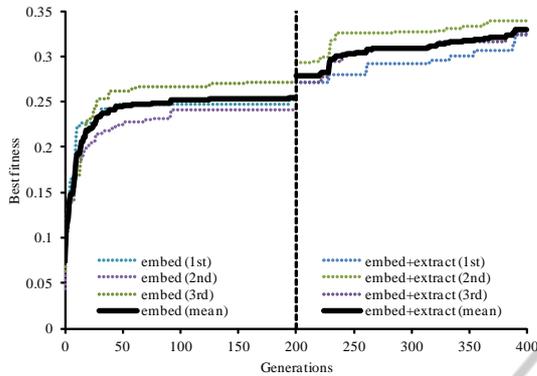


Figure 8: Fitness transitions during two-stage optimization.

1,280 pixels S-CG LCD and 12 megapixels CMOS sensor camera), as shown in Fig. 6. The tested cover 2D code and watermark images are shown in Fig. 3(a) and (b). The watermarked 2D codes were captured by a camera (Logicool HD Pro Webcam C920, 3 megapixels) to extract watermark.

We used Real-Coded Genetic Algorithm (RCGA) whose parameters were configured as shown in Table 1. The first-stage took 200 generations to evolve watermark embedding subbands, and then the second-stage did 200 generations to optimize extracting subbands in addition to embedding ones. The maximum watermark-embedding strength L_{max} was set to 192.

Three individual runs performed in the first stage of the search, and then three individual runs of the second stage performed. The three best individuals obtained by the first stage search were used as part of initial population of the second stage search.

4.2 Experimental Results

Fig. 8 shows the transitions of the best individual in the population during the two-stage optimization. The dotted lines denote the fitness values of independent runs, and the solid line describes the averaged value. Fig. 8 demonstrates that the second-stage search succeeded in finding better individuals than the best individual of the first-stage. In addition, the fitness of the best individual kept increasing even at around 400 generations, whereas the first-stage search converged after 100 generations; longer generation in the second stage would lead better solution.

The fitness value of the best solution exceeded 0.3, which was calculated from BCR values of the watermark images extracted from genuine and replicated 2D codes that were about 0.8 and 0.5, respectively. This means that the watermark can be decoded only from the genuine 2D code when the watermark 2D image is encoded with some error correctable code

which corrects more than 20 percent of the code.

Figs. 9 and 10 show example watermark schemes S_{1st} and S_{2nd} that correspond to best individuals (solutions) in the first- and second-stage, respectively. In both solutions, watermark images from replicated images were destroyed and only slight bleeds were left, whereas genuine successfully kept watermark patterns. As shown in Figs. 9(i) and 10(i), in watermark images extracted from original 2D codes, the watermark extracted by S_{2nd} involved less noise (black pixels) at white modules of watermark 2D code than that by S_{1st} . In addition, in watermark images extracted from replicas, S_{2nd} successfully removed the horizontal component of watermark better than S_{1st} , as shown in Figs. 9(j) and 10(j).

Table 2 shows the details of S_{1st} and S_{2nd} whose outputs were shown in Figs. 9 and 10. Focusing on the bright region of the cover 2D code image, the scheme S_{2nd} designed by second-stage search embedded the watermark into HH2, HL1, LH2, and LH3, whereas the first-stage solution S_{1st} embedded the watermark mainly into HL1; and S_{2nd} reconstructed the watermark from all the highest frequency subbands HH1, HL1, and LH1. This subband combination allows to facilitate the watermark destroy by replication at regions white circle modules of the covered 2D code.

In contrast, at dark region, S_{2nd} weakly embedded the watermark into HL1 only. However, the watermark was extracted from HH1 and HH3 in addition to HL1. This is because watermark embedded into HL1 gave rise to irregular but frequent vertical pattern as shown in Fig. 10(g), and this weak watermark was easily destroyed by replication.

In the case of edge regions of the cover 2D code image which were smaller than other regions, S_{2nd} used HL1 only similar to the dark region, whereas S_{1st} used HH1 and LH1. S_{2nd} reconstructed the watermark from HH1, HH2, HL1, and LH2. Similar tendency to the dark module regions could be seen in the edge regions.

5 CONCLUSIONS

This paper proposes a method for designing semi-fragile watermark for detecting 2D code replication. To realize a watermarking scheme with appropriate semi-fragileness, we introduced a new optimization technique as follows:

- Distinguishing subbands/strength levels between when embedding and extracting the watermark, which facilitates watermark reconstruction from more subbands than used for embedding. This

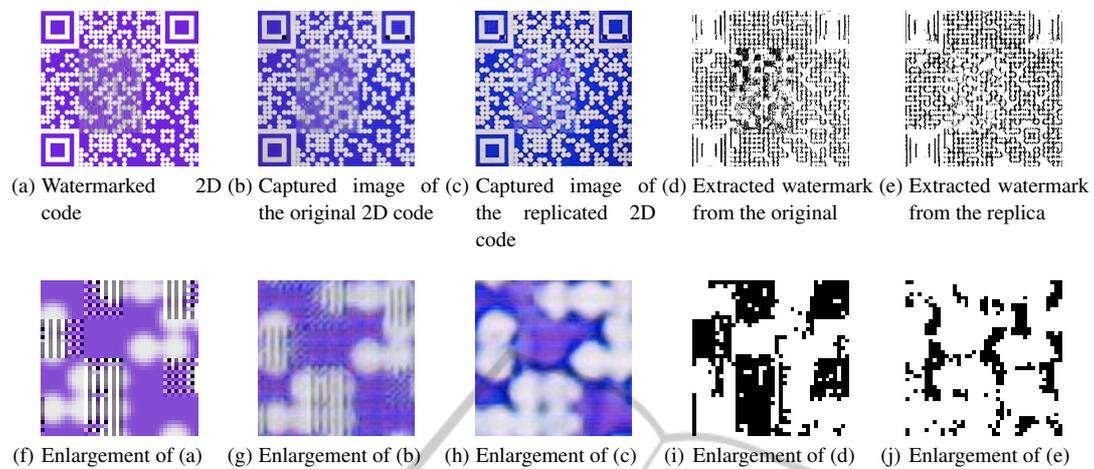


Figure 9: Example watermark images extracted from original and replicated 2D code designed by the first-stage optimization (embedding scheme only).

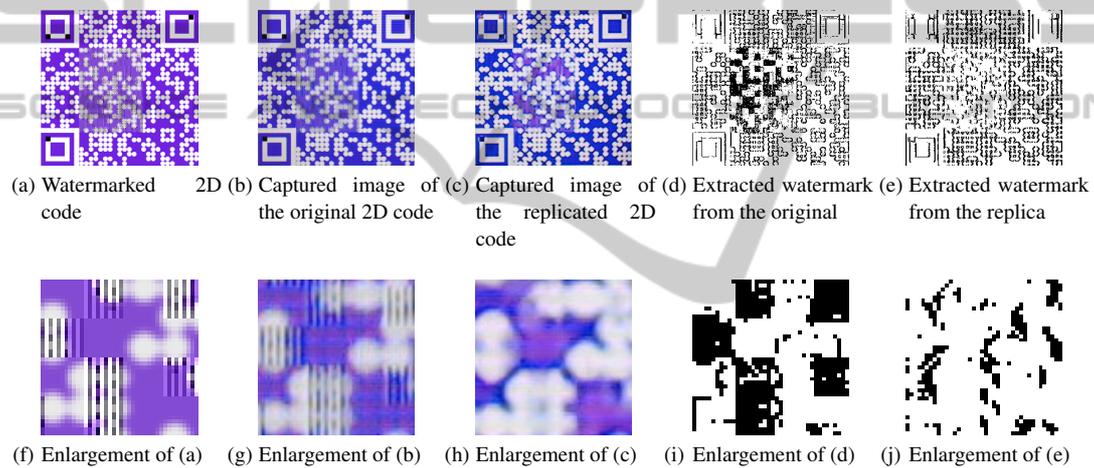


Figure 10: Example watermark images extracted from original and replicated 2D code designed by the second-stage optimization for embedding and extraction schemes.

Table 2: Obtained solutions by two-stage optimization.

			HH1	HH2	HH3	HL1	HL2	HL3	LH1	LH2	LH3	LL3
Bright region	First-stage		0.00	0.00	0.01	1.00	0.00	0.00	0.00	0.00	0.00	0.00
	Second-stage	embed	0.00	0.44	0.00	1.00	0.00	0.00	0.00	0.35	0.33	0.00
		extract	0.99	0.00	0.00	0.94	0.00	0.00	1.00	0.00	0.00	0.00
Dark region	First-stage		0.54	0.00	1.00	0.36	0.00	0.00	0.00	0.00	0.00	0.00
	Second-stage	embed	0.00	0.00	0.00	0.32	0.00	0.00	0.00	0.00	0.00	0.00
		extract	0.08	0.00	0.54	0.93	0.00	0.00	0.00	0.00	0.00	0.00
Edge region	First-stage		0.95	0.00	0.00	0.99	0.00	0.00	0.00	0.00	0.00	0.00
	Second-stage	embed	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
		extract	0.77	0.70	0.00	0.94	0.00	0.00	0.00	0.28	0.00	0.00

facilitates watermark extraction from images displayed on 2D code screens.

- Two-stage optimization, which allows to optimize subband selection and watermarking strength in both embedding and extracting scheme. Distin-

guishing embedding and extracting variables in the latter half of the search allows to efficiently find good solutions.

- Actual mobile phone based solution evaluation instead of simulation, which allows taking various

factors such as optical transfer function, distortion and various noise models into account without constructing a simulation model.

In future, we plan to apply multi-objective optimization (Ono et al., 2014) to make watermarking schemes robust against mobile phone screen types.

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REFERENCES

- Chu, S.-C., Huang, H.-C., Shi, Y., Wu, S.-Y., and Shieh, C.-S. (2008). Genetic watermarking for zerotree-based applications. *Circuits, Systems & Signal Processing*, 27(2):171–182.
- Eshelman, L. J. and Schaffer, J. D. (1993). Real-coded genetic algorithms and interval-schemata. In *Foundations of Genetic Algorithms*, volume 2, pages 187–202.
- Goldberg, D. E. (1989). *Genetic Algorithms in Search, Optimization, and Machine Learning*. Addison Wesley, Reading.
- Ho, A. T. S., Shen, J., Tan, H. P., and Woon, J. (2003). Security-printing authentication using digital watermarking. *SPIE International Technical Group Newsletter on Electronic Imaging*, 13.
- Huang, H.-C., Chu, S.-C., Pan, J.-S., Huang, C.-Y., and Liao, B.-Y. (2011). Tabu search based multi-watermarks embedding algorithm with multiple description coding. *Information Sciences*, 181(16):3379 – 3396.
- Kundur, D. and Hatzinakos, D. (1997). A robust digital image watermarking method using wavelet-based fusion. In *4th IEEE Int'l Conf. Image Processing*, pages 544–547.
- Kundur, D. and Hatzinakos, D. (1998). Digital watermarking using multiresolution wavelet decomposition. In *Acoustics, Speech and Signal Processing, 1998. Proceedings of the 1998 IEEE International Conference on*, volume 5, pages 2969–2972 vol.5.
- Loukhaoukha, K., Nabti, M., and Zebbiche, K. (2014). A robust svd-based image watermarking using a multi-objective particle swarm optimization. *Opto-Electronics Review*, 22(1):45–54.
- Mingzhi, C., Yan, L., Yajian, Z., and Min, L. (2013). A combined dwt and dct watermarking scheme optimized using genetic algorithm. *Journal of Multimedia*, 8(3).
- Ono, S., Maehara, T., Nakai, K., Ikeda, R., and Taniguchi, K. (2014). Semi-fragile watermark design for detecting illegal two-dimensional barcodes by evolutionary multi-objective optimization. In *Proceedings of Genetic and Evolutionary Computation Conference (GECCO) (Companion)*, pages 175–176.
- Ono, S., Maehara, T., Sakaguchi, H., Taniyama, D., Ikeda, R., and Nakayama, S. (2013). Self-adaptive niching differential evolution and its application to semi-fragile watermarking for two-dimensional barcodes on mobile phone screen. In *Proceedings of Genetic and Evolutionary Computation Conference (GECCO) (Companion)*, pages 189–190.
- Ono, S., Tsutsumi, M., and Nakayama, S. (2011). A copy detection method for colored two-dimensional code using digital watermarking. *The IEICE transactions on information and systems (Japanese edition)*, 94(12):1971–1974.
- Rao, K. R. and Yip, P. (1990). *Discrete Cosine Transform: Algorithms, Advantages, Applications*. Academic Press Professional, Inc., San Diego, CA, USA.
- Rey, C. and Dugelay, J.-L. (2002). A survey of watermarking algorithms for image authentication. *EURASIP Journal on Applied Signal Processing*, 6:613–621.
- Song, Y., Liu, R., and Tan, T. (2001). *Digital Watermarking for Forgery Detection in Printed Materials*, volume 2195/2001, pages 403–410. Springer Verlag.
- Vahedi, E., Zoroofi, R. A., and Shiva, M. (2012). Toward a new wavelet-based watermarking approach for color images using bio-inspired optimization principles. *Digital Signal Processing*, 22(1):153 – 162.