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Adaptive Digital Watermarking for Copyright Protection of CAD Data

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ABSTRACT

To protect against unlawful reproductions and distribution, the current paper proposes a digital watermarking technique for architectural drawings produced using a CAD system. First, the POLYLINEs are extracted from the drawing; then, an adaptive algorithm is used to embed a watermark in the characteristics of each POLYLINE. Next, the CIRCLEs are embedded using an adaptive watermarking algorithm related to the radius of circle from drawing. The proposed watermarking scheme is robust to various attacks, such as the geometrical transformation. Additionally, the proposed method satisfies the requirement of transparency for CAD program. It used AutoCAD 2002, which is commonly used as a CAD program for experiments. Experimental results confirmed the robustness and invisibility of the embedded watermarks in several conversions of an architectural drawing.

Keywords: Architectural design drawing, CAD, Digital watermarking, Geometrical attack, Copyright protection

1. INTRODUCTION

With the development of CAD systems, almost all architectural designs are completed using computer programs, which enable the drawings to be more detailed, more exact, and easier to see. However, as with most other computer files, CAD files are easy to copy and disseminate, making them vulnerable to illegal reproduction.

Several watermarking algorithms have already been developed with the main challenges being transparency and robustness[1]. Ruanaidh *et al.* [2] transferred the modulation features of the human visual system in the transform domain to solve the problem of compromise between robustness and transparency, while Voloshynovskiy *et al.* [3] proposed adequate stochastic modeling for content adaptive digital image watermarking. In addition, a watermarking technique with perceptual characteristics about successive subband quantization and a non-stationary Gaussian model in the multiwavelet transform domain has been proposed [4], and Ohbuchi *et al.* [5] presented a method of embedding a watermark in each vertex in a vector digital map, after dividing the vertices by rectangles that have vertices with a fixed quantity using a quad-tree method.

However, when watermarking a CAD drawing, the most important consideration is that a CAD drawing is a vertex-based image [6,7]. Various data transformations of DCT, DFT, DWT, and LOG POLA Mapping are currently available for raster-based 2-D images; therefore, image processing in frequency domains is already possible. Most multimedia watermarking schemes also use the fre-

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quency domain [8-10]. However, since CAD files are vector-based images rather than raster-based images, it is impossible to transform to frequency domain because there is no relation between neighborhood vertices. As such, frequency domain processing or mask processing, as in image watermarking, is impossible, leaving only spatial domain processing, which has the advantage of eliminating the attacks that affect the frequency domain. Nonetheless, architectural drawings are still vulnerable to many attacks, because handling data using a CAD tool is easy. Furthermore, CAD drawings are not damaged by enlargement or reduction, as they are vertex-based images and have vector characteristics. Therefore, when a CAD drawing is enlarged the embedded watermark must be transparent.

Accordingly, this paper proposes a copyright protection method for architectural drawings made using CAD tools, where a transparent watermark is embedded in POLYLINE and CIRCLE components using adaptive algorithms. Since one POLYLINE includes several LINE and ARC components, this maximizes the watermark capacity; plus, using the angle of the POLYLINE provides robustness to several attacks. The Seed Key is the difference between the angle values of the watermarked coordinates and those of the original coordinates; additionally, POLYLINE with only two vertices or the first three vertices in a straight line are excluded from watermark embedding. For CIRCLE watermarking, authenticity is determined based on the radius difference between the original and the detected watermarked circle. Experimental results confirmed that the embedded watermarks were visually imperceptible and robust against geometrical attacks, such as transparency, rotation, and cropping.

2. MODELING FOR DIGITAL WATERMARKING OF CAD DESIGN

2.1 CAD Watermarking Model

For the CAD watermarking, we analysis architectural drawings made by a CAD tool for architectural design, then embed a transparent watermark using the adaptive algorithm. Then, we develop a robust detection algorithm treating various data handlings as attacks, and thus, acquire and classify components as POLYLINEs and CIRCLEs in the architectural drawing. Then, we embed a watermark to angle and radius information of the components, because POLYLINEs have much more information of components than other CAD Data, and CIRCLE is the most significant component, and they are thus indispensable elements of architectural drawings. First, POLYLINEs and CIRCLEs in the architectural drawing are acquired and classified. Then, a watermark is embedded to POLYLINE's cosine value and CIRCLE's radius information in the drawing. A watermark with a Gaussian random sequence is embedded in the architectural drawing, and this algorithm has suitable embedding strength for transparency of the watermark. A watermark is used with a position key value with a binary bit sequence to decide the embedded position and sign. Additionally, they are composed in original positions again after watermark was embedded. Fig.1 shows the whole watermarking achievement process. When a water-

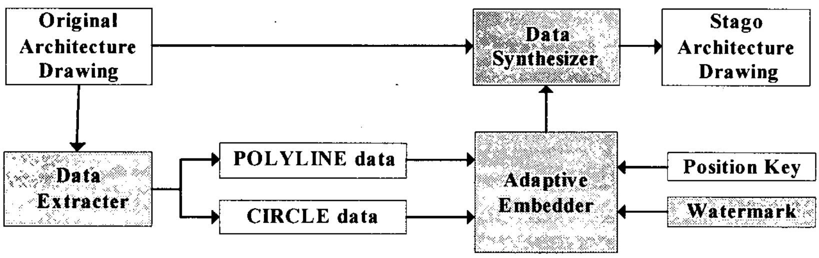


Fig. 1. Block diagram of the proposed watermarking embedding scheme.

mark is detected, they do not need the whole drawing of original, but only the components that were used when a watermark was embedded.

In the proposed watermarking scheme, the watermark detection algorithm does not need original drawing unlike most other algorithms. It needs only extracted data (POLYLINE, CIRCLE) when used in the watermark embedding scheme, and the correlation responses of watermark can be calculated by the extracted data and watermarked data. Therefore, because the leakage possibility of the original drawing is rarefied, the drawings can protect their copyright betterIn the same way, the proposed method can create a more robust algorithm achieving semi-blind watermarking.

Fig. 2 shows the whole proposed watermark detection algorithm. The similarity of each components is decided by *Seed Keys* as author's information.

2.2 Conditions that can be Regarded as Attacks and Distortion

- File format conversion: Watermarked drawings can easily change the format so that they can be used by other similar programs. For example, even if AutoCAD private file is converted by using DWG and DWT, DWS, and DXF, a watermark must be not damaged.
- Cropping: A watermark should still be detectable when a cropped portion of the original drawing is inserted into the attacker's drawing.
- Translation: A watermark that is embedded to the ingredient must not lose changes by means of movement of design drawing, or replacement of two ingredients in case they are elements of the same shape.
- Rotation: An attacker can rotate watermarked drawing by necessity. A watermark must not be broken in such cases.
- Scaling: A watermark should be able to be detected in all size changes of the whole drawing or only in a specified portion.

It should be considered preferentially about attacks. This algorithm can be robust in such attacks, and at the same time the user can't know of the existence of watermark.

In the meantime, architectural design drawing has no degradation of image quality like other vertex-based images even if the drawing is magnified or reduced by software. Therefore, distortions can

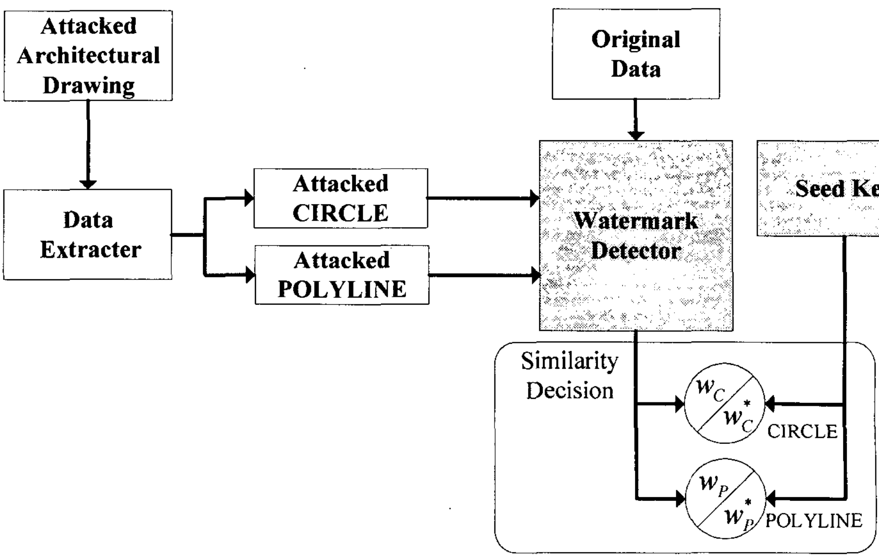


Fig. 2. Block diagram of the proposed watermark detection scheme.

occur in the design drawing because of the watermark, when the drawing is magnified. Therefore, the embedded watermark must consider the distortion rate of the drawing, and these offenses shall not be detected well if the drawing is magnified extremely.

3. PROPOSED CAD WATERMARKING ALGORITHM

3.1 POLYLINE Watermarking

POLYLINE Embedding Scheme. One POLYLINE has as many LINEs and ARCs as designer demands in the drawing. Therefore, it is the component that is most useful in the drawing, and large parts of the drawing can be damaged by loss of one POLYLINE. Fig. 3 shows an example of POLYLINE's application in an architectural drawing.

This POLYLINE consists of 4 LINEs and 1 ARC. ARC has one more factor as an expansion coefficient, except x and y coordinates. A watermark is embedded in these first 3 vertices because this watermarking scheme makes an imaginary triangle by using the first 3 vertices in one POLYLINE. Watermark embedding in a POLYLINE's coordinate value is same as (1).

$$p^*_{mn} = p_{mn} + \alpha_P \cdot w_{mn} \tag{1}$$

Where p^*_{mn} and p_{mn} are each coordinates in which the watermark is embedded, and n is a vertex order in one POLYLINE having *1, 2, 3*. Additionally, m is the number of POLYLINEs used in watermark embedding (m=0,1,2, ..., MAX). It needs distortion index α_P or watermark's transparency. Watermark w_{mn} is random sequence of Gaussian distribution including the binary bit string as position key k_{mn}. The coordinate value that watermark is embedded is decided by k_{mn} as (2).

$$p_{mn} = \begin{cases} x_{mn}, & if \quad K_{mn} = 0 \\ y_{mn}, & if \quad K_{mn} = 1 \end{cases} \tag{2}$$

Here, an angle between the first three vertices can be calculated in the watermarked POLYLINE. In this method, the *Seed Key* is the difference of the angles of the watermarked coordinates and original coordinates, and POLYLINEs having only two vertices or having first three vertices on a straight line, are excepted from watermark embedding because serious problems can happen when getting a Seed Key or calculating the correlation response in (6). Figure 4 shows difference of the angles regarded as the watermark. Fig. 4 shows the watermarked POLYLINE by (1) from Fig 3.

The embedded watermarks make change of the angle between each component as in Fig. 4. θ^*_m is a angle that was distorted by watermarks and θ_m is a original angle in the POLYLINE. The calculation of angles is possible by (3) using *The Second Cosine Laws* from Fig. 5.

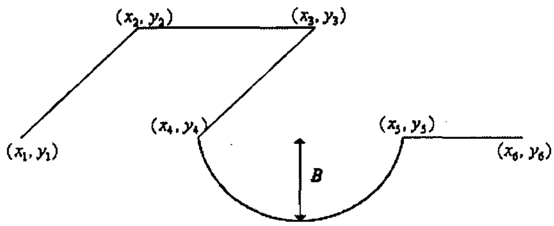


Fig. 3. The composition of POLYLINE in the architectural drawing.

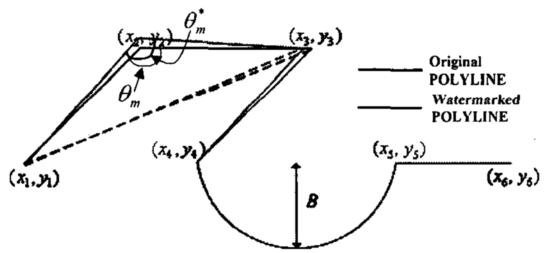


Fig. 4. Changed cosine value of watermarked POLYLINE.

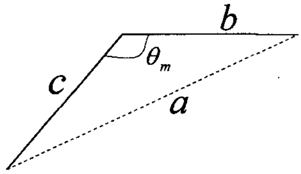


Fig. 5. Angle in triangle at The Second Cosine Raw.

$$\cos\theta_m = \frac{b^2 + c^2 - a^2}{2bc} \quad (3)$$

Finally, the author's information as *Seed Key* D_m is generated as difference values of angle by (4).

$$D_m = \cos\theta_m^* - \cos\theta \quad (4)$$

Fig. 6 compares the original drawing and the watermarked one. This method shows the watermark's transparency as adjustment α_P in which a user cannot confirm distortion of drawing by the embedded watermark as in Fig. 6.

Watermark Detection Scheme of POLYLINE Data. Because we used cosine information of POLYLINE when we embedded the watermark in POLYLINE, it can consist of the detection process that calculates the cosine value of attacked POLYLINE's first three vertices coordinates. Additionally the original drawing is not needed in watermark detection process. The watermark detection achieves by (5)

$$D_m^* = \cos\bar{\theta}_m^* - \cos\theta \quad (5)$$

where $\bar{\theta}_m^*$ is the cosine value of the attacked POLYLINE's first three vertices coordinates, D_m^* is the difference of original POLYLINE's cosine value and the attacked. Similarity of detected watermarks is calculated as (6) comparing the detected *Seed Key* D_m^* with the original *Seed Key* D_m

$$Sim(D_m, D_m^*) = \frac{D_m \cdot D_m^*}{\sqrt{D_m^* \cdot D_m^*}} \quad (6)$$

3.2 CIRCLE Watermarking

CIRCLE Embedding Scheme. Although CIRCLE is not widely used in architectural drawing, it is a necessary element in drawing circles, and it is included in all the drawings. CIRCLE consists of a circle's emphasis and a radius r in architectural drawing. This CIRCLE watermarking technique presents a simple algorithm that embeds a watermark to radius r of the CIRCLE using (7)

$$r_n^* = r + (\alpha_C \cdot w_n) \quad (7)$$

where r_n^* is the radius of watermarked CIRCLE, and α_C is the distortion of CIRCLE Watermarking.

Fig. 7 expresses transparency of watermark by distortion index α_C. As a result, α_C is fixed by 0.001 in this paper.

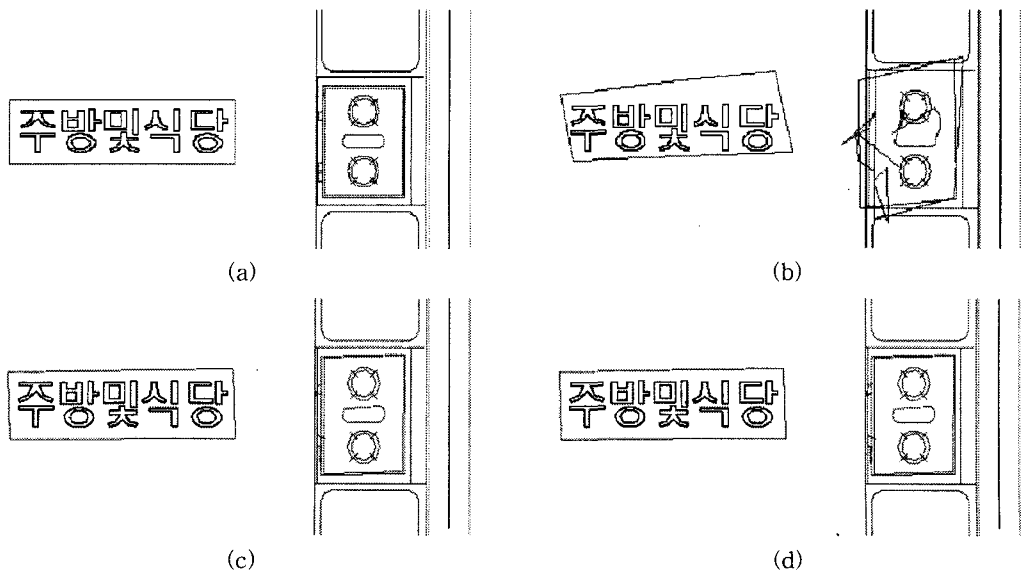


Fig. 6. Transparency of the POLYLINE watermarking. (a) Original drawing ($\alpha_P = 0$), (b) $\alpha_P = 0.1$, (c) $\alpha_P = 0.01$, and (d) $\alpha_P = 0.001$.

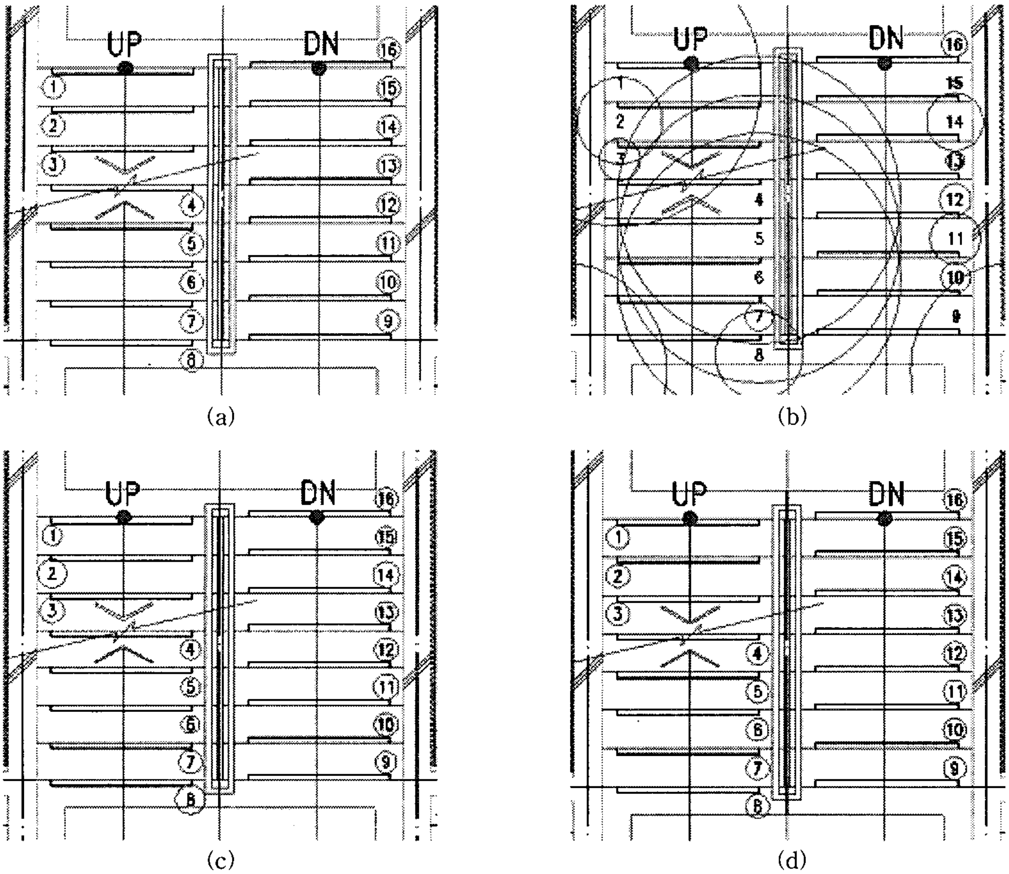


Fig. 7. Transparency of CIRCLE watermarking according to distortion index α_C. (a) Original ($\alpha_C = 0$), (b) $\alpha_C = 0.1$, (c) $\alpha_C = 0.01$, (d) $\alpha_C = 0.001$.

Watermark Detection Scheme of CIRCLE Data. In CIRCLE watermarking, watermark detection is achieved by calculating the difference of attacked radius and original radius at (8).

$$\omega_C = (\vec{r}^{*} - r) / \alpha_c \tag{8}$$

Finally, the attacked watermark ω_C is compared with original watermark w_n by (9), and is calculated the similarity about CIRCLE watermarking.

$$Sim(w, \omega_C) = \frac{w \cdot \omega_C}{\sqrt{\omega_C \cdot \omega_C}} \tag{9}$$

4. EXPERIMENTAL RESULTS

This paper used drawings that are manufactured by 'AutoCAD 2002' tool for experiments of proposed watermarking algorithm of the architectural drawings, and selected '*Center floor detailed drawing*' and '*Stair section-detail drawing*' as the main testing bench for efficient experiments of the proposed method. After each POLYLINE and CIRCLE is extracted, watermark is embedded in them. The key watermark was used as the 500th seed of 1000 Gaussian random sequences. The distortion index α_P and α_C were 0.001 and 0.001 for the watermark's transparency. For the convenience of experiments, there were alternated D_m and D_m^* with the 500th keys in POLYLINE watermarking. We embedded POLYLINE and CIRCLE in 2 drawings for correct results of the experiments. 443 watermarks were embedded in 998

POLYLINE in '*Center floor detailed drawing*' and 186 watermarks were embedded in 186 CIRCLE '*Each part detailed drawing*'. Because there are no developed benchmarks about watermarking of architectural drawing, we investigated the robustness of POLYLINE and CIRCLE as attacks that describe to 2.2 and confirmed the correlation responses.

Fig. 8 shows watermarked drawings and correlation responses of detected watermarks. The *seed key* was alternated by the 500^{th} seed voluntarily for the convenience of the experiments. Because we used each different characteristic key value, the forms of (e) and (f) are different.

As can be seen in Fig. 6 and 7, watermarks were embedded transparently in architectural design drawings, and it was confirmed that they can be detected with a unique key value. When they were not attacked, POLYLINE's similarity was 48.54 and CIRCLE's similarity was 13.18.

Table 1 is shown experimental results of correlation response, after changes in the embedded

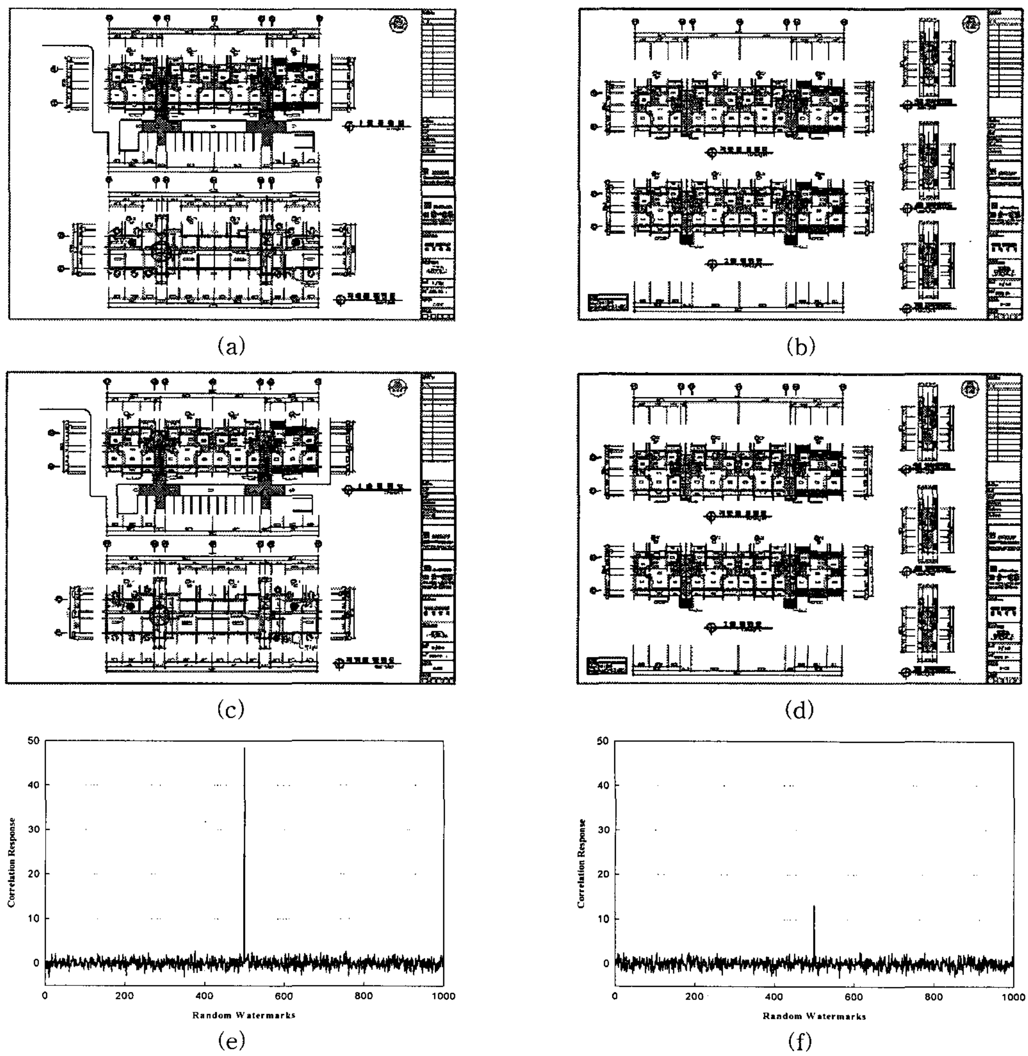


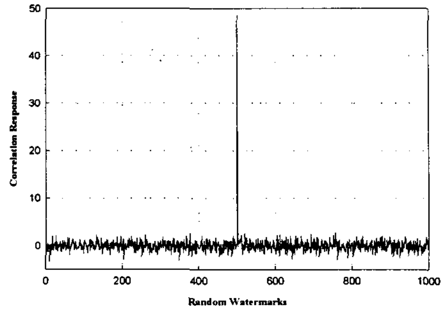
Fig. 8. Results of proposed watermarking in architectural design drawing (a) and (b) are original drawings, (c) watermarked POLYLINE of (a), (d) watermarked CIRCLE of (b), and (e) and (f) display each similarities of (c) and (d).

architectural design drawing in other formats-available to other similar software. It can know that there is no damage of all watermarks in POLYLINEs and CIRCLEs. Fig. 9 shows the result of moving positions of each block from the watermarked drawings, and the similarity to Fig. 10 after that attack.

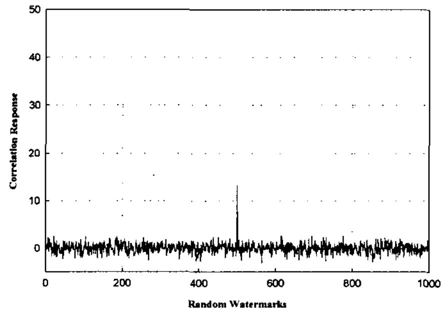
Table 1. Watermarks damage by file format conversion

Format	DXF (2002)	DWG	DWT	DWS	DXF (early)
POLYLINE	48.54	48.54	48.54	48.54	48.54
CIRCLE	13.18	13.18	13.18	13.18	13.18

In Fig. 10, regarding position translation as attack, after changing the positions of all blocks, the watermark was not lost entirely. Fig. 11 and 12 show drawings after the different various attacks such as rotation, expansion and reduction. Fig. 13 and 14 show the correlation responses after doing such processes regarded as attacks.

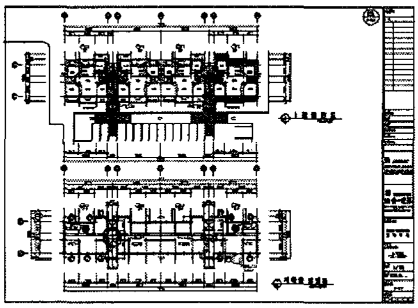


(a)



(b)

Fig. 10. Similarities of watermark after translations attack in Fig. 7. (a) CR=48.54, (b) CR=13.18.


(a)

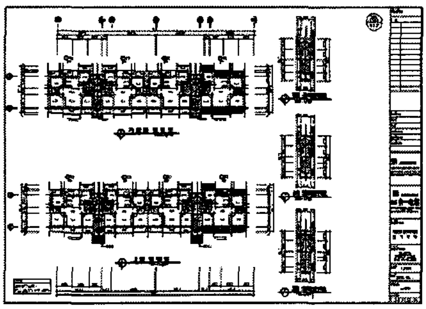
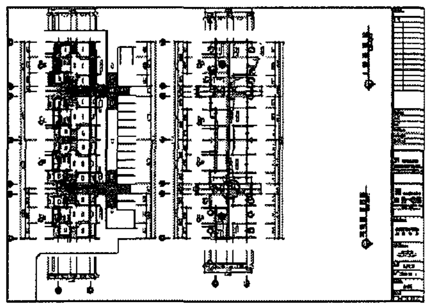

(b)

Fig. 9. Translations of watermarked drawings as attack. (a) Attacked POLYLINE, (b) Attacked CIRCLE.


(a)

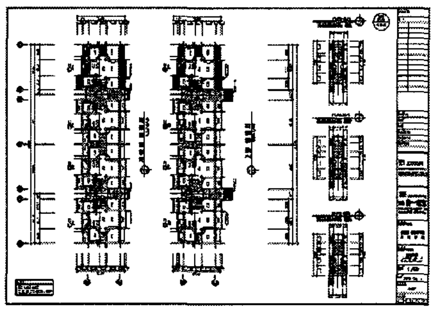
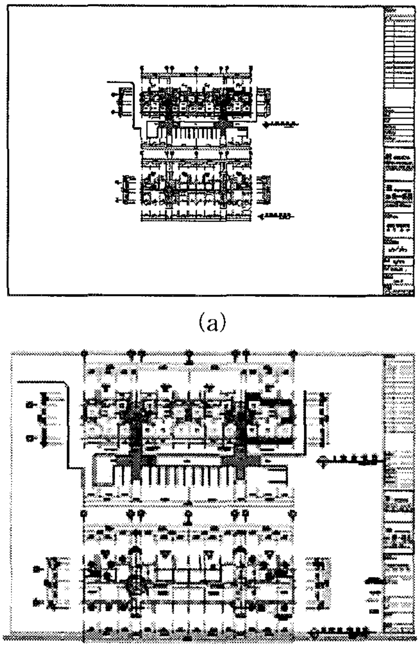

(b)

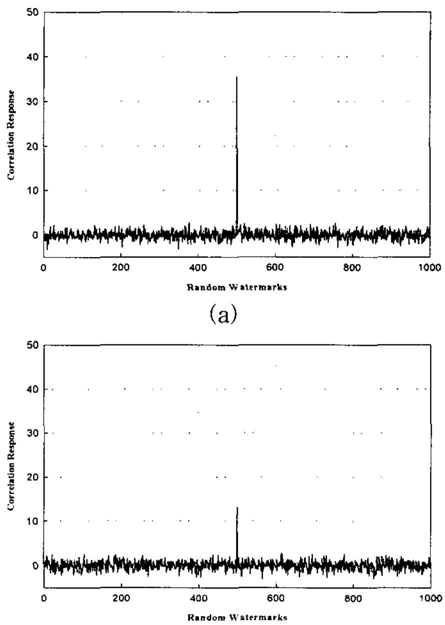
Fig. 11. Rotations of watermarked architectural designed drawings as attack. (a) Attacked POLYLINE, (b) Attacked CIRCLE.



(a)

(b)

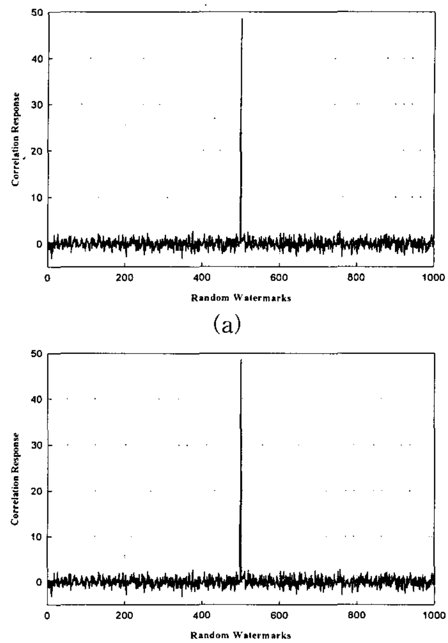
Fig. 12. Scaling of watermarked architectural designed drawings. (a) and (b) are each expanded and reduced drawings of POLYLINE embedding.



(a)

(b)

Fig. 13. Similarities of watermark after rotation attack in Fig. 9. (a) CR=35.56, (b) CR=13.18.



(a)

(b)

Fig. 14. Similarities of watermark in POLYLINE after scaling attack in Fig. 10. (a) Reduction (CR=48.54). (b) Expansion(CR=48.54).

Fig. 12 shows the correlation responses of Fig. 11, about rotation attack. Watermarks in POLYLINE and CIRCLE were not damaged. In Fig. 14, although the watermark embedded in POLYLINE was attacked with scaling, we could identify robustness of the embedded watermark. Fig. 15-(a) and (b) show cropping attacked drawings in POLYLINE watermarking.

5. CONCLUSIONS

Given the increasing circulation of multimedia digital information, the market demand for digital watermarking technology for copyright protection has increased. But digital watermarking technology may be generalized forward. It is clear that the standard of contents protection technology exerts enormous influence in digital economy.

In this paper, we proposed a robust watermarking algorithm in geometrical attacks using POLYLINE, and CIRCLE in architectural drawing. There are

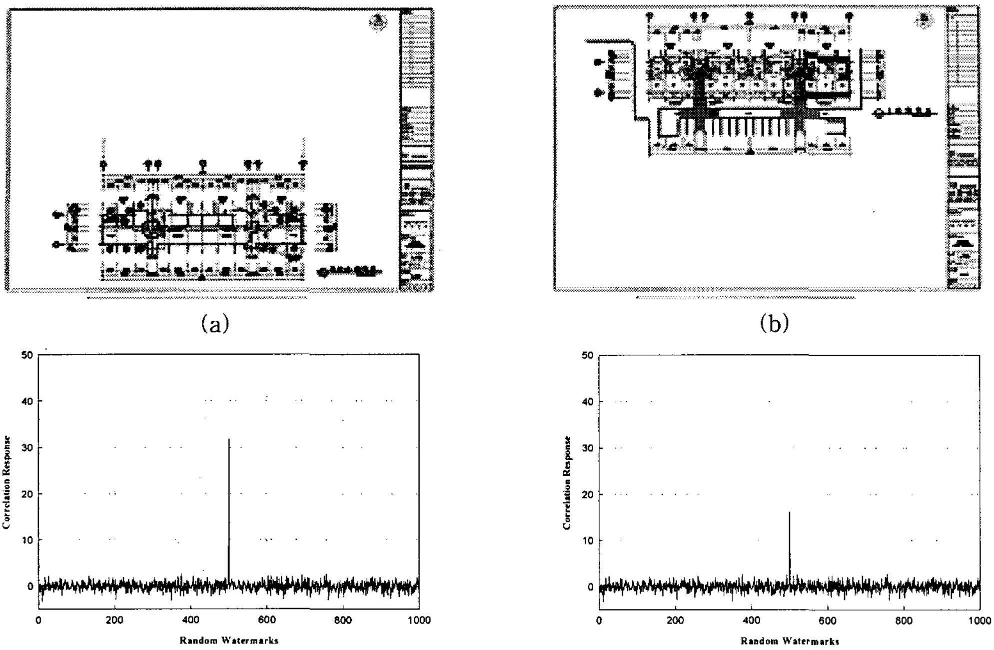


Fig. 15. Cropping of POLYLINE watermarking. (a) Cropping_type 1. (b) cropping_type 2. (c) Correlation response of (a) (CR=31.81). (d) Correlation response of (b) (CR=16.13).

different algorithms for each component. Additionally semi-blind watermarking that has a secure detection algorithm is included in this method. In experimental results, the proposed watermarking method had not perceptual artifacts and it had robust characteristics under various kinds of conditions such as geometrical or another attacks. These results can help ensure that copyright of design technology is protected by intellectual property. Accordingly, we are going to ready copyright protection of exposed architectural design drawing. The proposed method can be applied to watermarking for 2-D images based on vertex.

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