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Digital Watermarking for Copyright Protection of 3-D CAD Design Drawing Based on Vector Data Using Digital Watermarking

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ABSTRACT

There has been more increased the development of 3D technique since many 3D contents of 3D graphic model, 3D mobile/computer game, and3D CAD have been serviced in Web or industry fields. Therefore, the watermarking system is more required to protect the copyright for 3D contents. Currently there has been researched about the watermarking for 3D graphic model of mesh or NURBS. However, watermarking technique based on CAD design drawing leaves something to be desired yet. This paper proposed the watermarking technique for 3D CAD design drawing using Line and Arc components. After drawing out Line and Arc components from designed drawing, we embed the watermark into both the length of Line component and the radius of Arc component. Experimental results verified that the proposed algorithm satisfies the transparency about watermarked drawing and also has the robustness against several attacks by using public CAD tool.

Keywords: Design drawing, 3D CAD, Digital Watermarking, Geometrical Attack, Copyright Protection

1. INTRODUCTION

With increasing 3D graphics model in content industry such as 3D movie or 3D CAD, 3D model watermarking has been become an important technique for the copyright protection of 3D content. Recent information-communication technology has the characteristics of open and distributed networking and no confrontation but user's convenience. Because of these characteristics, digital contents that are provided in digital communication can be easily unlawfully duplicated, edited, saved and distributed, which called the inverse function of digital information. Since anyone can't distinguish these unlawful contents from original contents, there have been raised serious problems of indiscreet reproduction and copyright violation. Generally there are two technologies for the intellectual property and copyright protection; cryptography and watermarking. The cryptography technology cut off the access of the unauthorized person after the multimedia information is encrypted. However, it cannot prevent the unlawful action of an authorized person and cannot solve the problem that some copyright owners assert their ownerships for one content. To solve the problems of the cryptography, there have been much researched in watermarking technology, which is the

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end-step in information security and protects the copyright of owner by embedding the watermark into the multimedia information.

Watermarking research is progressing actively to solve this problem, and many algorithms are proposed. Cox et al. [1] presented watermarking algorithm Spread Spectrum method. Podilchuk et al. [2] presented watermarking algorithm with visual model used JND (just noticeable difference).

These algorithms can't applied to 3D contents and there have been no effective methods of copyright protection for 3D contents such as 3D computer graphics, 3D game, 3D CAD/CAM, 3D animation and so on. Since these 3D contents have been widely used in commercial industry, 3D watermarking technique has been essential to protect the copyright of 3D contents and has begun to study. Ohbuchi et al. presented watermarking for 3D polygonal model through geometric and topological modification [3]. Mao et al. presented watermarking for 3D geometric model through triangle subdivision [4]. Beneden et al. also presented an algorithm that adds a watermark by modifying the normal distribution of the model geometry [5]. Kanai et al. presented watermarking for 3D polygons using multiresolution wavelet decomposition [6]. Ohbuchi *et al.* presented watermarking for 3D polygonal meshes in the mesh spectral domain [7] and presented method that the watermark is embedded into to each of vertices after dividing rectangles that have vertices of fixed quantity based on quadtree way in Vector Digital Map [8]. Furthermore, they presented watermarking based on frequency domain approach of 3D shape models [9]. Jang et al. presented watermarking about 2D CAD architectural design drawing that the watermark is embedded into line, circle, arc and polyline of vector data [9].

In this paper, we proposed a robust watermarking algorithm for copyright protection using Line and Arc Layer in 3D CAD design drawing. 3D CAD design drawing is composed of vector data instead of graphic data in general image. Therefore, we obtain components of Line and Arc Layer in 3D CAD design drawing and embed the watermark according to Line and Arc characteristics. Experimental results confirmed the robustness of the embedded watermark against various attacks and also the good transparency of the watermark. In section 2, we will describe the modeling for digital watermarking of 3D CAD data in brief. Section 3 gives the proposed algorithm of Line watermarking and Arc watermarking. And then, we will describe the experimental results in section 4. Finally we will conclude this paper in section 5.

2. MODELING FOR DIGITAL WATERMARKING OF 3D CAD DATA

Most watermarking algorithms for audio, image and video have been presented on the basis of transform domain such as DCT, DFT, DWT, Log Polar Mapping considering both of robustness and invisibility. CAD data has the characteristics of vector based image unlike general raster based image and has difficulty in using frequency transformation because there is no relation of neighborhood vertex information. Recent there has been proposed watermarking algorithm for 3D polygonal meshes using 3D wavelet transformation of vertex data. But 3D CAD data consists of layers that is the information of short pieces and is independent of each other. Thus 3D wavelet transformation can't be applied at 3D CAD data. Therefore, 3D CAD watermarking needs processing in spatial domain based on geometrical structure. And it may consider not attacks in frequency domain but geometrical attacks using public CAD tools.

This paper proposed simple and robust watermarking algorithm for 3D CAD design drawing that is designed by CAD tool with the above characteristics. The proposed algorithm acquires and classifies the components of Line and Arc in the 3D design drawing. Line and Arc components are basic component in 3D CAD drawings and

many drawings have a number of Line and Arc components. The watermark that is generated by Gaussian random sequence is embedded into length and radius information of two components. Our algorithm has a suitable embedding strength for transparency of the watermark. Fig. 1 shows the process of the proposed watermarking algorithm.

3. PROPOSED WATERMARKING ALGORITHM

The proposed watermarking algorithm consists of LINE watermarking and Arc watermarking. The watermark is used as a random sequence of Gaussian distribution. Each of watermarking algorithms is respectively explained in detail.

3.1 LINE Watermarking

3.1.1 Watermark Embedding

A Line, one of components that are handled in most design drawings, consists of a beginning vertex coordinate $1(x_0, y_0, z_0)$ and an ending vertex coordinate (x_1, y_1, z_1) and only these vertex coordinates must be considered to the embedding target in Line component. The watermark is embedded into the extracted Line components from 3D CAD drawings. And the watermarked drawings can be obtained by synthesizing the watermarked Line components and other components. The watermark must be embedded into vertex coordinates transparently by distortion index α_L so that users cannot recognize the embedded watermark. Fig. 2 shows the block diagram of the proposed embedding algorithm in Line components.

A nth. extracted Line component C_n can be defined as $(x_{n0}, y_{n0}, z_{n0}, x_{n1}, y_{n1}, z_{n1})$. One value w_n of watermark is embedded into components of an arbitrary vertex coordinate among Line component $C_n = (x_{n0}, y_{n0}, z_{n0}, x_{n1}, y_{n1}, z_{n1})$.

$$C_n^* = C_n + \alpha_L \cdot w_n \tag{1}$$

The length of Line component is used for extracting the watermark. Thus, the difference of LINE length in original drawing and LINE length in watermarked drawing is calculated.

$$D_n = (L_n^* - L_n)/\alpha_L \tag{2}$$

where $L_n^* = \sqrt{(x_{n1} - x_{n0}^*)^2 + (y_{n1} - y_{n0}^*)^2 + (z_{n1} - z_{n0}^*)^2}$

$$L_n = \sqrt{(x_{n1} - x_{n0})^2 + (y_{n1} - y_{n0})^2 + (z_{n1} - z_{n0})^2}$$

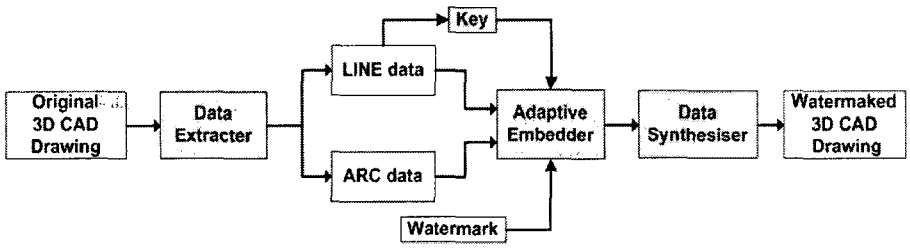


Fig. 1. The block diagram of the proposed watermarking algorithm.

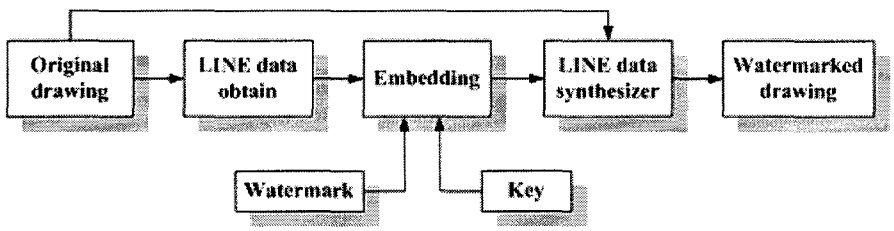


Fig. 2. The block diagram of LINE embedding algorithm.

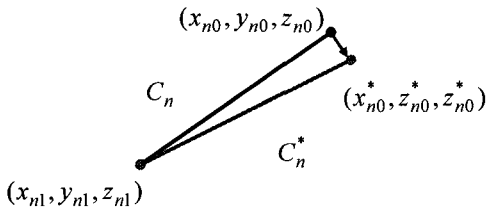


Fig. 3. Embedding a watermark into one vertex coordinate among a Line component C_n.

The length difference is used to calculate the correlation for watermark extracting. Thus, the length difference and LINE components for embedding in original drawing are required to extract the watermark.

A distortion index α_L in eq. (1) is an embedding intensity in trade-off relation between robustness and transparency. Fig. 4 shows the part of drawings according to various distortion indices. In this paper, α_L is determined to 0.00001 experimentally. Users or attackers must be unable to recognize the embedded coordinates. The watermarked drawing can be obtained by synthesizing watermarked LINE components and other components.

3.1.2 Watermark Detecting

To detect watermark the difference between length L'_n of LINE components in attacked drawing and length L'_n of stored LINE components in original drawing is calculated as follows;

$$D'_n = (L'_n - L_n)/\alpha_L \tag{3}$$

where $L'_n = \sqrt{(x'_{n1}-x'_{n0})^2 + (y'_{n1}-y'_{n0})^2 + (z'_{n1}-z'_{n0})^2}$

$(x'_{n0}, y'_{n0}, z'_{n0}, x'_{n1}, y'_{n1}, z'_{n1})$ are components of attacked Line C'_n. The correlation of the line length difference D_n that is stored in watermark embedding and the line length difference D'_n in watermark detecting is calculated as follows;

$$Sim(D_n, D'_n) = \frac{D_n \cdot D'_n}{\sqrt{D'_n \cdot D'_n}}. \tag{4}$$

3.2 ARC Watermarking

3.2.1 Watermark Embedding

The components of Arc Layer are obtained from 3D CAD design drawing. The structure of ARC as shown in Fig. 5 can be used to embed the watermark. C is a center point of circle that describes an Arc and R is a radius of Arc on the basis of C and P is a reference axis to calculate an angle

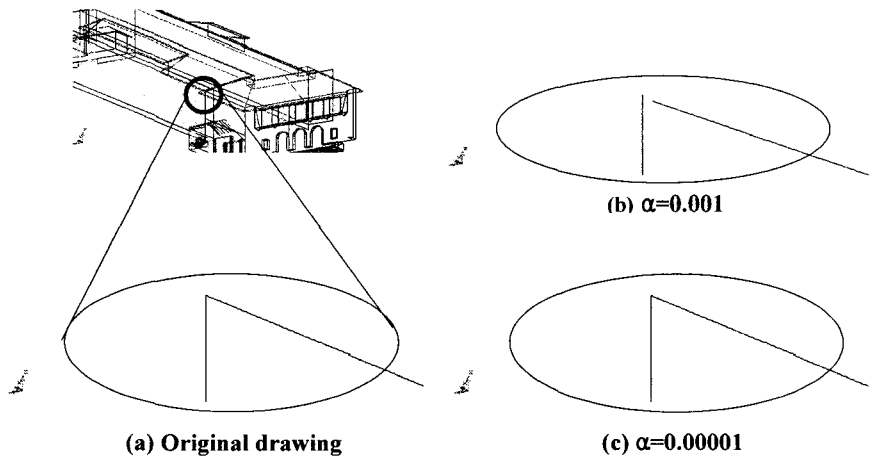


Fig. 4. Distortions of 3D CAD design drawing by α_L factor. (a) Watermarked 3D CAD drawing $\alpha_L = 0.00001$, (b) $\alpha_L = 0.1$ and (c) $\alpha_L = 0.0001$.

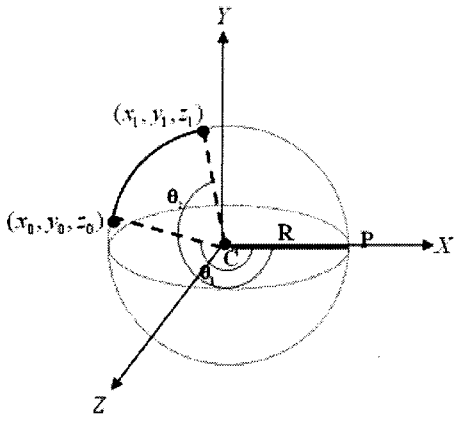


Fig. 5. The structure of ARC in 3D design drawing.

of Arc point. (x_0, y_0, z_0) and (x_1, y_1, z_1) represent a beginning point and an end point of Arc. θ_0 is an angle between a beginning point and a reference axis and also θ_1 is an angle between an end point and a reference axis. Thus, an Arc consists of a center point, a radius, two points and angles, and a reference axis.

After drawing out only Arc components in 3D CAD design drawing, the proposed algorithm embeds the watermark into Arc's radius. Thus, nth watermark component w_n is embedded into a radius R_n in a nth selected Arc component as follows;

$$R_n^{\cdot} = R_n + \alpha_R \cdot w_n \tag{5}$$

An embedding strength α is determined to 10^{-7} experimentally since it is trade-off relation of robustness and invisibility. Fig. 7 shows the distortion rate according to an embedding strength α_R. A Watermarked 3D CAD design drawing is obtained by synthesizing watermarked Arc components and other components as similar as Line watermarking. Radius values for embedding are stored to detect the watermark.

3.2.1 Watermark Detection

The process of watermark detection is similar as the process of watermark embedding. After drawing out Arc components in attacked design drawing, the watermark w'_n is detected into radius component R'_n in Arc components.

$$w'_n = (R'_n - R_n)/\alpha \tag{6}$$

The correlation of watermark is calculated by

$$Sim(w_n, w'_n) = \frac{w_n \cdot w'_n}{\sqrt{w'_n \cdot w'_n}} \tag{7}$$

comparing the detected watermark w'_n and the original watermark w_n.

4. EXPERIMENTAL RESULTS

We experimented with 3D CAD drawings, Campus and Watch that are designed by 'AutoCAD 2002' tool as shown in Fig. 8. After drawing out each of Line components and Arc components in Campus and Watch drawings, the watermark, which are generated by 200th seed of 1000 Gaussian random sequence, is embedded into two components respectively. Embedding strengths,

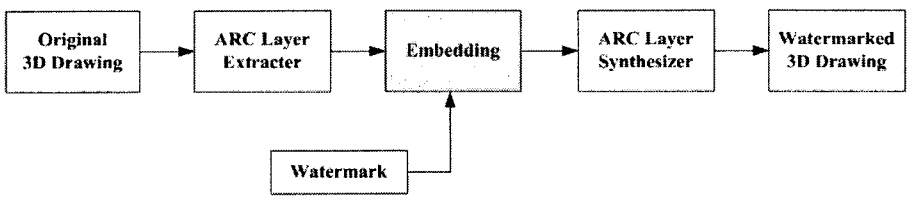


Fig. 6. The block diagram of Arc embedding algorithm.

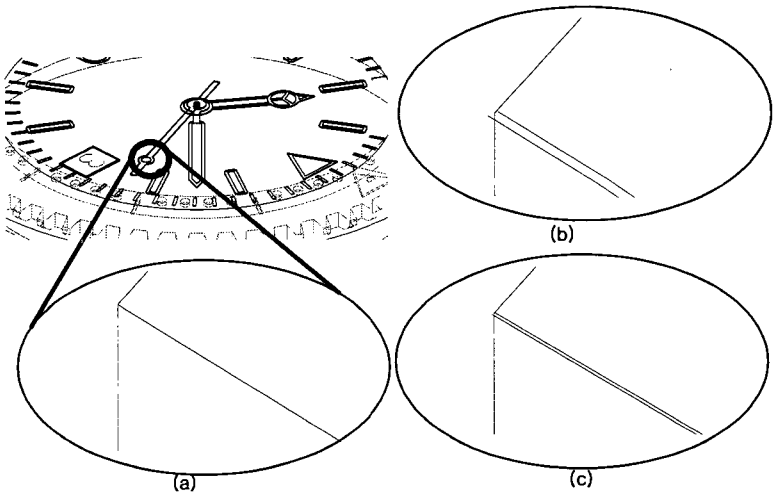


Fig. 7. Distortions of 3D CAD design drawing by α_R factor. (a) Watermarked 3D CAD drawing $\alpha_R = 10^{-7}$, (b) $\alpha_R = 10^{-4}$ and (c) $\alpha_R = 10^{-5}$.

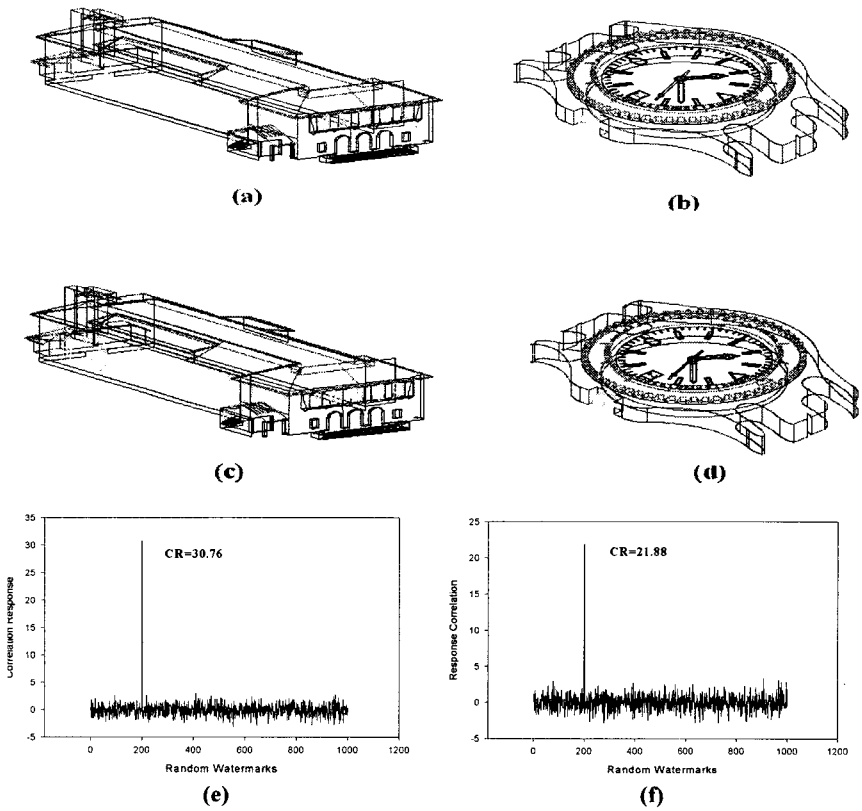


Fig. 8. Results of the proposed watermarking for 3D CAD design drawing. (a) Campus and (b) Watch drawings, (c) watermarked Campus, (d) watermarked Watch, (e) and (f) correlations of (c) and (d).

α_L in Line watermarking and α_R in Arc watermarking are 10^{-6} and 10^{-7}. 3D CAD design drawing has various distributions of basic components such as Line, Arc, Circle and 3DFACE according to the drawing structure. For example, Campus drawing has many Line components rather than other components as shown in Fig. 8 (a). However, Watch drawing has many Arc components rather than other components as shown in Fig. 8 (b). In our experiment, we embedded the watermark into Line in Campus drawing and Arc in Watch drawing respectively. Thus, for Campus drawing, the watermark with 1000 length is embedded into 1000 components that are randomly selected among total 1130 Line components. And also the watermark with 500 length is embedded into 500 components that are randomly selected among total 1770 Arc components for Watch drawing. Watermarked Campus and Watch drawings are shown in Fig. 8 (c) and (d). These figures verified that the watermark is invisible. The correlation responses of original watermark and detected watermark in Campus and Watch are shown in Fig. 8 (e) and (d). From these figures, we know that the correlation of 200th seed is highest. If watermarked drawings don't be attacked, the correlations are 30.76 in Line watermarking and 21.88 in Arc watermarking.

Recently there is no the standard evaluation for watermarking performance, since there has been not yet developed watermarking for 3D CAD design drawing beside our proposed algorithm. In this paper, we evaluated the robustness of the proposed algorithm against file format conversion, cropping, translation, rotation, and scaling.

3D CAD drawings can be easily changed to file format by using any CAD tools. For example, there are file formats such as DWG, DWT, DWS and DXF, which are AutoCAD private files. The watermark must be not damaged in these file format conversions. Table 1 shows the experimental results of correlation response in file format conversion. In file format conversion experiment, a watermarked drawing is changed to DXF, DWG, DWT and DWS format and then the watermark is detected from its changed drawing. Table 1 verifies that there is no damage of watermark both in Line and Arc watermarking.

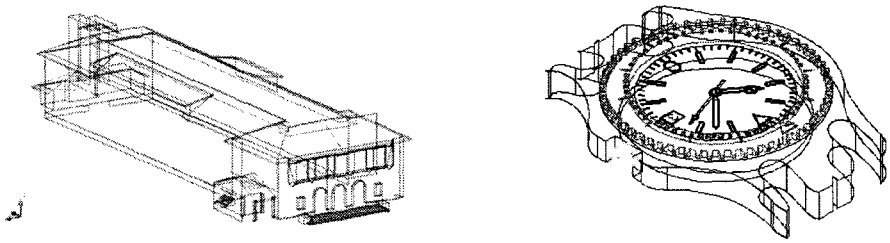
The important part of 3D CAD drawing can be intendedly used for designing other drawings. Although any part of drawing is cropped, the watermark must be detected in other part of drawing. The whole design drawing or only parts of drawing may be translated to arbitrary position and rotated to arbitrary angle and also scaled to arbitrary scale ratio. Furthermore, there may be replaced many ingredients in several designs with the same structure. The watermark must be detected against these geometrical attacks. Fig. 9 shows that the watermarked Campus and Watch designs are translated to arbitrary position and the correlation responses of the detected watermark in these designs are shown in Fig. 10. All watermarks can be detected against translation.

Fig. 11 shows that the watermarked Campus and Watch designs are rotated to arbitrary angle and Fig. 12 shows the correlation response of watermark in rotated designs. From these figure, we know that the detected watermarks don't be damaged in rotation attacks.

For scaling experiment, we performed up-scal-

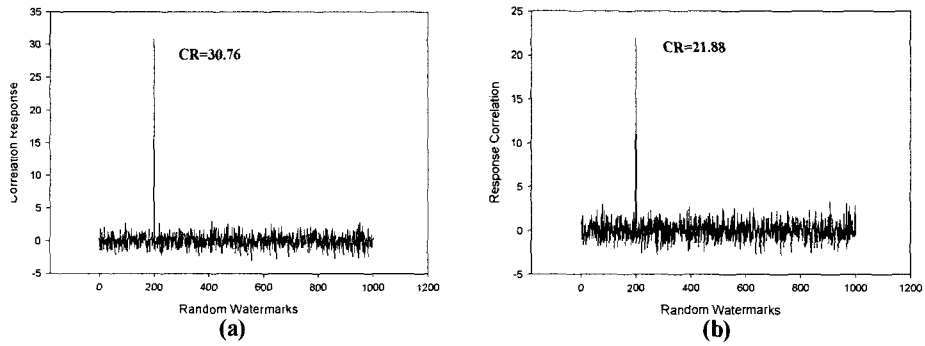
Table 1. Correlation response of the detected watermark in file format conversions

Format	DXF	DWG	DWT	DWS
Line	30.76	30.76	30.76	30.76
Arc	21.88	21.88	21.88	21.88



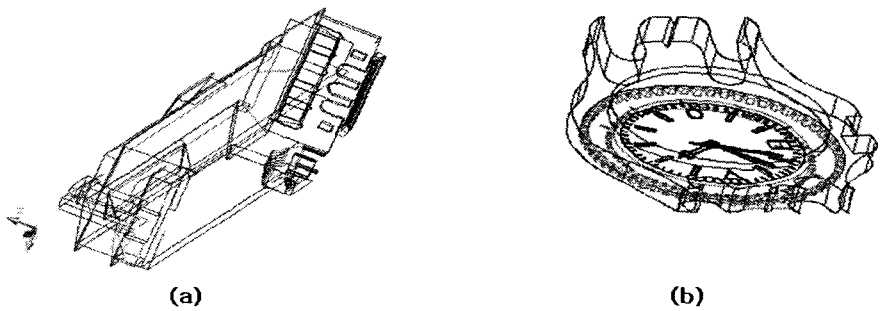
(a) (b)

Fig. 9. Translation of the watermarked (a) Campus and (b) Watch design to arbitrary position.



(a) (b)

Fig. 10. Correlation of watermark after translations attack in Fig. 9. (a) 30.76 and (b) 21.88.



(a) (b)

Fig. 11. Rotations of watermarked (a) Campus and (b) Watch drawings to arbitrary angle.

ing of expansion or down-scaling of reduction. Up-scaled Campus design and down-scaled Watch design are shown in Fig. 13. Since the correlation responses of the watermark in these designs are 30.76 and 21.88, the waterarmk are not damaged against scaling attacks.

For cropping experiment, we cropped about 30% components in watermarked Campus and Watch designs as shown in Fig. 14. The correlation response of the detected watermark decreases in proportion to cropping amount. Table 2 shows the correlation responses to translation, rotation, scaling and cropping attacks. This table confirms that the watermark don't be damaged against translation, rotation, scale, cropping attacks.

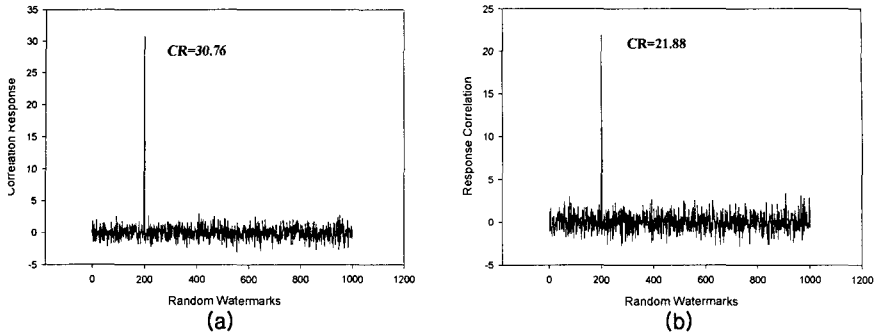


Fig. 12. Correlation of watermark after rotation attack in Fig. 11 (a) 30.76 and (b) 21.88.

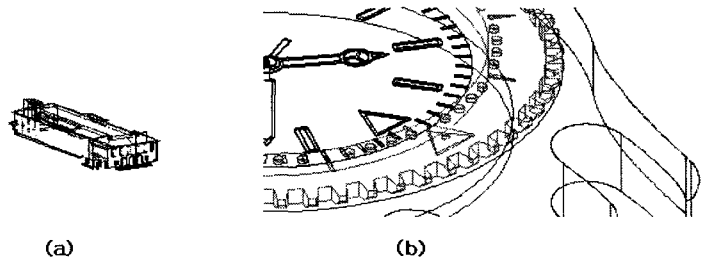


Fig. 13. Scaling of watermarked 3D CAD designed drawings. (a) down-scaled Campus with 30.76 correlation response and (b) up-scaled Watch with 21.88 correlation response.

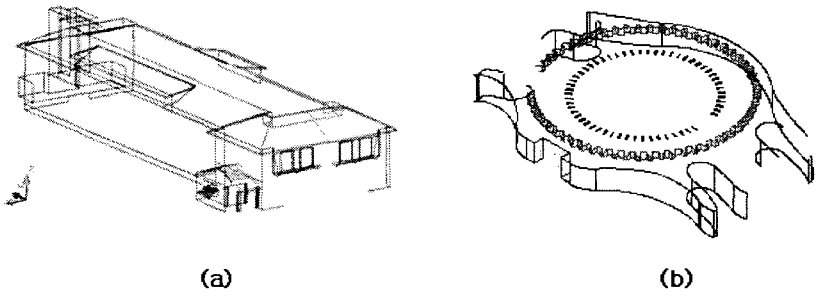


Fig. 14. Cropping of watermarked 3D CAD designed drawings as attack. (a) And (b) were 30% cropping.

Table 2. Correlation responses to translation, rotation, scaling and cropping attacks

Attack	Original	Move	Rotation	Scale	Cropping (30%)
Line	30.76	30.76	30.76	30.76	26.75
Arc	21.88	21.88	21.88	21.88	15.18

5. CONCLUSIONS

In this paper, we proposed Line and Arc water-marking scheme for 3D CAD design drawing with robustness against geometrical attacks. Experimental results verified that the watermark is invisible as

anyone can't recognize the embedded watermark in design drawing as well as It is robust since the correlation response in drawing with file format conversion, translation, rotation and scaling attacks is the same as the correlation in the watermarked drawing and the correlation response in cropped drawing is about 26.75 at Line watermarking and 15.18 at Arc watermarking. We think that the proposed algorithm help to protect the copyright in industry fields though the watermark don't robust against all attacks.

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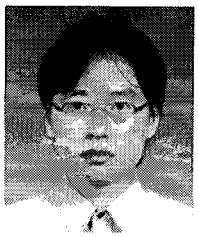

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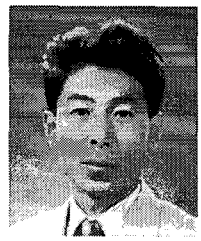

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