JOURNAL OF KOREA MULTIMEDIA SOCIETY, VOL. 10, NO. 12, DECEMBER 2007(pp. 1601-1611)

Geometric CAD Watermarking System Using Line, Arc, Circle Components in Architectural Design Drawings

Bong-Ju Jang[†], Suk-Hwan Lee[††], Ki-Ryong Kwon[†††], Kwang-Seok Moon[††††]

ABSTRACT

In this paper, we presented geometric CAD watermarking scheme for Architectural design drawings using line, arc, and circle components to prevent infringement of copyright from unlawfulness reproductions and distribution. The conventional CAD watermarking scheme can be applied to both line and arc components. But the proposed scheme consists of line, arc and circle watermarking schemes for three basic components of CAD design. After extracting line, arc and circle components from designed drawing, the watermark is embedded into the length of Line component, the angle of arc component, and the radius of circle component considering the robustness against various geometric transformations. The embedding strengths in each component are determined to be preserving the transparency of the watermark. By experimental result, we confirmed the robustness and the invisibility of embedded watermarks in several conversions of architectural design drawing.

Keywords: Design Drawing, Geometric CAD Watermarking, Geometrical Attack, Copyright Protection

1. INTRODUCTION

Many researchers have developed digital watermarking scheme for audio, image, video and graphics model for copyright protection while trying to achieve real application [1-7]. Recently most architectural design drawings have been made by CAD software tools that can be more detailer, exacter and easier to be observed. But CAD data can be copied, edited and diffused like as most of digital data. Sometimes we have seen same parts at some building drawings and also watched plagiarizing cases of another architectural design drawings in TV news. Therefore the watermarking scheme for CAD data of design drawings has been required to prevent plagiarizing cases of design drawings. This scheme must be considered the relation of trade-off between watermark's transparency and robustness [1] like as general watermarking schemes. Thus, the embedded watermark in architecture drawing must not be observed by users and not be damaged or detected by other designers. Furthermore, it can be specially robust against various attacks though it is possible modifications and distortions without any limit as using CAD tools.

Ohbuchi et al. [5] presented watermarking scheme for vector digital map that divides rectangles consisting of vertices with fixed quantity using quad-tree method and then embeds the watermark into each vertex in rectangle. But, these algorithms breed an overhead by addition of re-

※ Corresponding Author : Kwang-Seok Moon, Address : (608-738) 599-1 Daeyeon-dong, Nam-gu, Busan, Korea, TEL : +82-620-6465, FAX : +82-620-6450, E-mail : moonks@pknu.ac.kr

Receipt date : Oct. 8, 2007, Approval date : Nov. 21, 2007

† Division of Elec. Computer, and Telecomm. Eng., Pukyong National University (E-mail : roachjbj@korea.com)

†† Dept. of Information and Computer Engineering, Tongmyong University (E-mail : skylee@tit.ac.kr)

††† Division of Elec. Computer, and Telecomm. Eng., Pukyong National University (E-mail : krkwon@pknu.ac.kr)

†††† Division of Elec. Computer, and Telecomm. Eng., Pukyong National University (E-mail : moonks@pknu.ac.kr)

※ This work was supported by Korea Research Foundation Grant (KRF-2004-002-D00289).

dundant mesh and fragile to noise addition and global modification. Benedens [6] proposed a watermarking method that modifies the model's normal distribution to store information solely in the geometry of the model making this algorithm robust to vertex randomization, remeshing, and mesh simplification. However, if the watermarked model is attacked by partial resection, such as cropping, the watermark embedded in that section disappears, whereas for an affine transformation, the algorithm needs to be realigned using the normal distributions of the original model. Lee et al. [7] proposed 3D mesh watermarking using the CEGI distribution that is robust against mesh simplification, cropping, vertex randomization, and rotation and does not require the original model for realignment or extracting the watermark. 3D watermarking schemes can't applied to CAD design drawings, since CAD design drawing is consist of some layers that have the basic components such as line, arc, circle and Polyline unlike 3D polygonal model.

This paper proposed the watermarking scheme using geometric structures of line, arc and circle for architectural design drawings made by CAD tools based on the conventional digital map [8] and CAD watermarking [9]. The algorithm presented in [8] can adapted for both line and arc components. The algorithm presented in [9] embeds the watermark bitstream into the ratio of the length of target lines and a curvature radius on the basis of a center point in a arc component and the ratio of two sides in a polygonal face component.

In our algorithm, we analyze layer structure of architectural design drawings and then embed the watermark into line, arc and circle components by using geometric characteristics of each component. Thus, the embedding targets of each component are the length difference in line component, the angle difference in arc component, and the radius in circle component. From experimental results, the artifacts by the embedded watermark can't be observed by users and the watermark was not damaged or detected by other designers. And the watermark showed robustness against geometrical attacks like as transparency, rotation and cropping.

2. CAD DATA WATERMARKING CONDITIONS

Various data transformations of DCT, DFT, DWT, LOG POLA Mapping etc. are available in case of raster based 2-D images. Most multimedia watermarking schemes are based on frequency transform. But, since CAD design drawing has the characteristic of vector based image unlike general raster based image and it has no relation with neighborhood vertices, it is impossible to apply frequency transform in CAD data. Recently many researches about 3D wavelet transform similar as subdivision method have been achieved for progressive rendering of 3D polygonal models. But 3D wavelet transform can't be applied to CAD data since it is composed of many short pieces with vertices that are independent each other. Therefore, spatial processing based on geometric characteristics should be only possible in CAD watermarking scheme.

Also, there are some kinds of attack that can be performed in watermarked architectural drawings by using popular CAD tools. The following lists are typical attacks in CAD drawings.

1) *File format conversion* : Watermarked drawings can be easily changed to another format so that users use them in several CAD tools. There are many formats for CAD drawings such as DWG, DWT, DWS, and DXF etc. Even if watermarked drawings will be changed to another format, the watermark must be not damaged. 2) *Cropping* : Users can remove some parts of watermarked drawing. Though some parts of the watermarked drawing will be removed, the watermarked must be detected in remain parts. 3) *Translation* : Basic components of line, arc and circle can be moved to arbitrary position preserving the same shape.

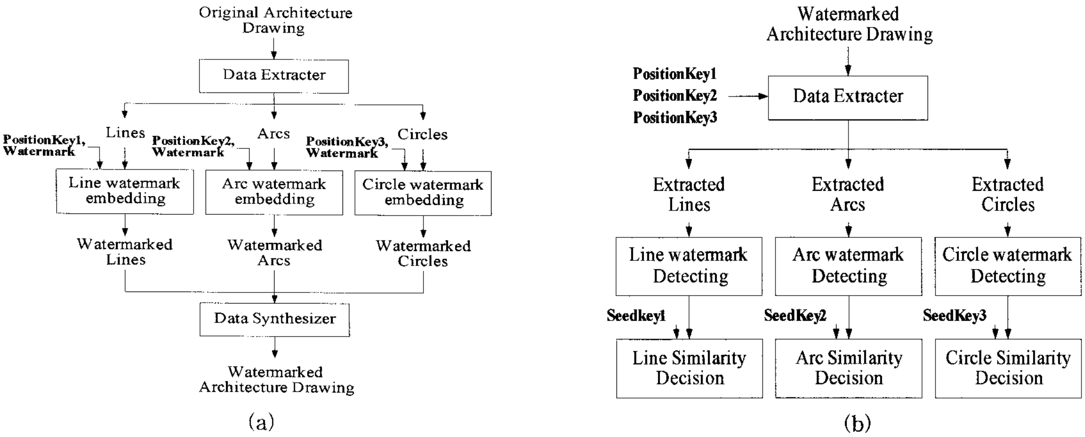


Fig. 1. The proposed watermark (a) embedding and (b) detecting process.

And also two components can be replaced by each other. Though the movement or the replacement of components, the watermark must be detected. 4) *Rotation* : Attacker can rotate the whole or some parts of watermarked drawing to arbitrary direction. 5) *Scaling* : The size of whole drawing or some specified parts can be magnified or reduced to arbitrary scale factor. The watermark must not be broken in such cases. 6) *Hybrid attacks* : Attackers can perform some attacks together. For example, after removing some specified parts, the watermarked drawing can be rescaled again to the same size of original drawing.

It should be considered preferentially about attacks. The proposed algorithm can be robust against the above attacks and verify that users cannot know existence of watermark. Also, watermarked drawing has no effect on quality even if it enlarges or reduces extremely in CAD tools. Thus, the geometric distortion by the watermark can't offend with the eye though enlarging the watermarked drawing.

Fig. 1 shows the proposed watermark embedding and detecting processes.

3. PROPOSED WATERMARKING SCHEME

The proposed scheme consists of line, arc, and circle watermarking schemes as shown in Fig. 1. Three watermarking schemes are explained respectively as following sections. But we used the watermark extracting method for line, arc and circle components based on the conventional extracting method [8].

3.1 Line Watermarking

3.1.1 Watermark Embedding

Line is the basic component of design drawing compared with other components. A line consists of a beginning point coordinate (x_1,y_1) and an end point coordinates (x_2,y_2). Actually, the watermark can be embedded into coordinates of two vertices. Line embedding process is performed by mapping to the drawing with watermarked line components after extracting line components from designed drawing. Fig. 2 shows line embedding process.

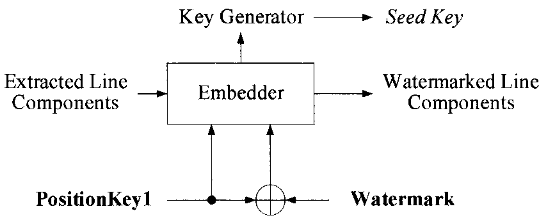


Fig. 2. The watermark embedding process in line component.

The watermark is used as the Gaussian random sequence and it includes binary bit stream of position key. One of watermark is embedded into all coordinate values (x_1, y_1, x_2, y_2) of a line component. Firstly, the embedding position in a line component is decided by two position key bits $k_n k_{n+1}$ as follows.

$$P_n = \begin{cases} x_1, \text{ if } k_n k_{n+1} = 00 \\ y_1, \text{ if } k_n k_{n+1} = 01 \\ x_2, \text{ if } k_n k_{n+1} = 10' \\ y_2, \text{ if } k_n k_{n+1} = 11 \end{cases} \quad k_{\max} = w_{\max+1} \tag{1}$$

The first key bit k_n decides the sign s_n of original watermark.

$$s_n = \begin{cases} +1, \text{ if } k_n = 0 \\ -1, \text{ if } k_n = 1 \end{cases} \tag{2}$$

P_n is the coordinate value that nth. watermark component will be embedded. Thus, the watermarked coordinate value P_n^* is calculated by

$$P_n^* = P_n + \alpha_L \cdot s_n \cdot w_n. \tag{3}$$

α_L is the distortion index with the relation of trade-off between robustness and transparency. The proposed algorithm computes the length of original line and watermarked line including the watermarked value P_n^* and then get the difference value D_n between two lengths. The difference value $D_n (n \in [1, N])$ is used as *Seed Key* and stored to detect the watermark. For example, if $k_n k_{n+1} = 01$, the difference value D_n is

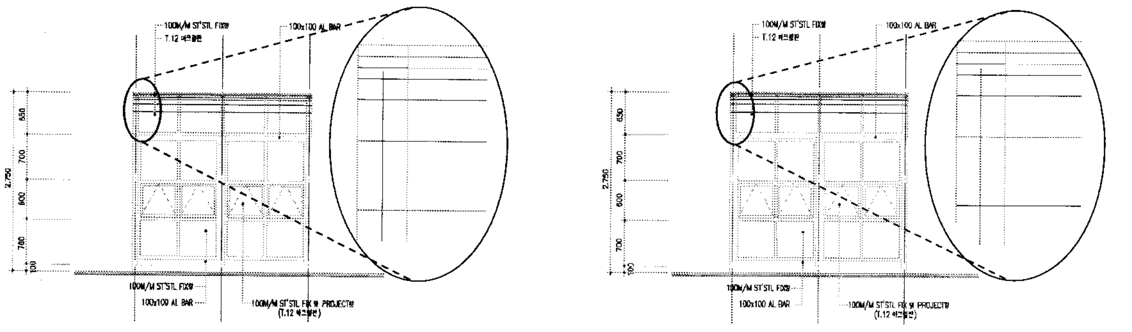
$$D_n = \left(\sqrt{(x_2 - x_1)^2 + (y_2 - P_n^*)^2} - \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}\right) / \alpha_L \tag{4}$$

An original CAD data and w_n used in the embedding process are not necessary in the extracting process. It needs only extracted line components from the original CAD data. The proposed line watermarking scheme will be robust against rotation, translation, cropping, and other attacks as long as line's length doesn't be changed above the range of distortion index. Furthermore, the transparency can be satisfied because a watermark component is embedded into one coordinate value in two vertices according to the distortion index. Users can't know what's the position and coordinate point that the watermark is embedded and also the embedding sign by the position key bit. Fig. 3 shows the distortion rate according to distortion index α_L.

3.1.2 Watermark Detecting

Since the proposed algorithm use the length of line for the watermark embedding, the detecting process firstly computes the length of line in attacked drawings by using seed key and then computes the difference value D_n^*. If position key bits $k_n k_{n+1} = 01$, D_n^* is

$$D_n^* = \left(\sqrt{(x'_2 - x'_1)^2 + (y'_2 - p'^*_n)^2} - \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}\right) / \alpha_L \tag{5}$$



(a) (b)

Fig. 3. (a) Original architectural design drawing and distorted drawings by (b) α_L=0.01.

x'_1, x'_2, p'^{*}_n, y'_2 are coordinated values in attacked line component. The similarity of the detected watermark is calculated by Eq. (6) comparing the detected seed key D^*_n with original seed key D_n.

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

If $-1 < D_n < 1$, the correlation response of D_n and D^*_n will be smaller than w_n because D_n and D^*_n have square term. Therefore, the similarity of D_n and D^*_n will be smaller than the correlation response of w_n and w^*_n, but the correlation response of w_n and D^*_n will be much smaller than the correlation response w_n and w^*_n. The difference of matched *Seed Key*'s similarity and not matched one become increase extremely. It can help claim copyright more certainly by author.

3.2 Arc Watermarking

3.2.1 Watermark Embedding

We confirmed that line watermarking scheme has the robustness against some attacks through experiments. But its scheme has the complexity and the difficulty for correcting abstraction in scaling attack because it needs the pre-processing calculating the scaling factor and resizing again. For supplementing this weakness, we embed the watermark into arc and line at the same time. Fig. 4 shows the structure of arc layer in architectural design drawing.

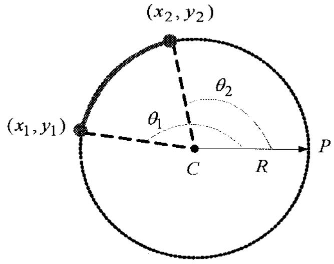


Fig. 4. The Structure of an arc layer in architectural design drawing.

As shown in Fig. 4, C is an origin of arc and R is a radius and P is a reference axis of angles θ_1, θ_2 from a beginning point (x_1, y_1) to a destination point (x_2, y_2). Since these angles are stable about geometrical transformation of rotation, scaling, and translation and human's sight does not recognize the delicate change of angle, the proposed arc watermarking scheme selects two angles θ_1, θ_2 for embedding target. After extracting arc components in architectural drawing and searching angles θ_1, θ_2, the embedding position is selected as one of two angles. Thus, a watermark is embedded into angle θ_1 if the position key K is -1 and angle θ_2 if K is 1.

$$K = \begin{cases} -1 \text{ if } \theta_1 \leq 3^0 \text{ and } \theta_2 < 357^0 \\ 1 \quad else \end{cases} \quad (7)$$

The proposed algorithm uses Eq. (7) to prevent

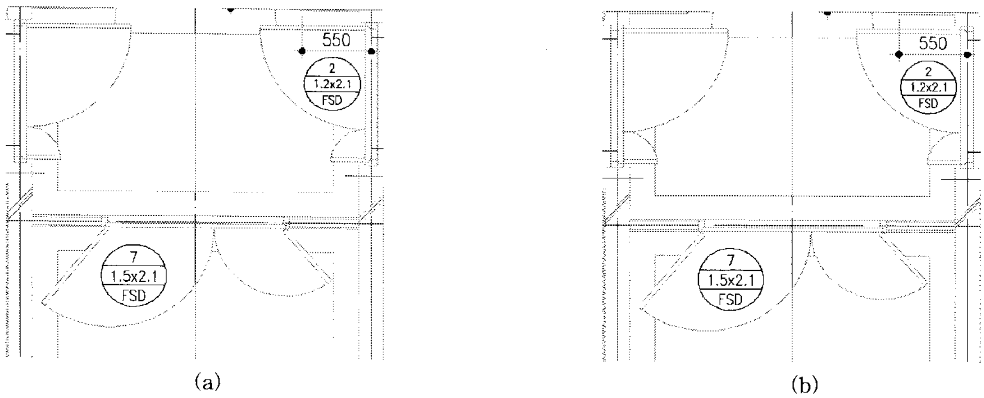


Fig. 5. (a) Original drawing and (b) watermarked drawing by arc watermarking scheme.

the case that angle value become negative or over 360 degree by the watermark. After selecting the position key K, the watermark is embedded into the selected angle.

$$\theta_n^* = \theta_n + \alpha_A \cdot K_n \cdot w_n \qquad (8)$$

θ_n^* and θ_n are the watermarked angle and original angle in n th extracted arc component. α_A is the distortion index of arc watermarking and decided to 1 experimentally. Since the watermark can be detected by the difference between angles θ_1, θ_2, position key K acts to find the sign of watermark in the detecting process. The watermarked angle θ_n^* is inserted in nth arc component. Fig. 5 shows the original drawing and watermarked drawing in α_A=1. From this figure, we know that user can't confirm the distortion of drawing by the watermark visually.

3.2.2 Watermark Detecting

The watermark can be detected by the difference of angle values as follows

$$w_A = \{(\theta_2 - \theta_1) - (\theta_2^* - \theta_1^*)\}/\alpha_A \qquad (9)$$

$\theta_2 - \theta_1$ and $\theta_2^* - \theta_1^*$ represent difference of two angles in original drawing and watermarked drawing. The similarity of watermark is calculated by comparing the detected watermark w_A and original watermark w.

$$Sim(w, w_A^*) = \frac{w \cdot w_A^*}{\sqrt{w_A^* \cdot w_A^*}} \qquad (10)$$

The angles of arc may be influenced in some case of design drawing processed by some operations. For example, if any arc that has 2 degree angle is changed to -3 degree, the angle value of arc will be 359 degree actually. In this case, the arc is excluded from the watermark detecting process. Finally, the correlation response of watermark is calculated by the similarity between w_A and w.

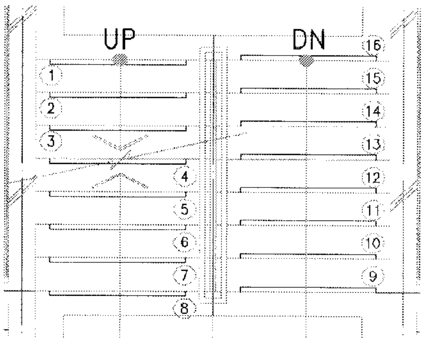
3.3 Circle Watermarking

3.3.1 Watermark Embedding

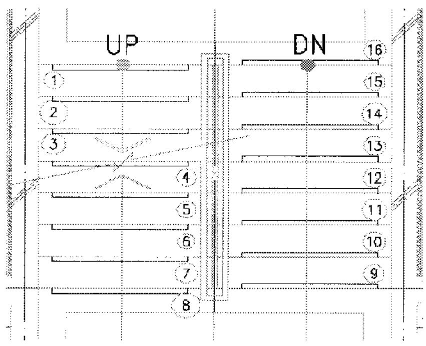
Although circle is more less used than line and arc in architecture drawing, it is more expressive component and is included in all drawings. Furthermore, circle can't be manufactured easily because it is used to express the essential indispensability. A circle component consists of an origin C and a radius R. The proposed circle watermarking scheme embeds the watermark w_n into radius R_n of nth extracted circle component.

$$R_n^* = R_n + \alpha_C \cdot w_n \qquad (11)$$

R_n^* is the watermarked radius and α_C is the distortion index of circle watermarking. Fig. 6 shows the transparency of watermark by distortion index



(a)



(b)

Fig. 6. (a) Original architectural drawing and distorted drawings by (b) α_C=0.01.

α_C. From this results, α_C is determined to 0.001 in this paper

3.3.2 Watermark Detecting

The watermark can be detected by calculating the difference of attacked radius and original radius.

$$w_C^* = (R^* - R)/\alpha_C \tag{12}$$

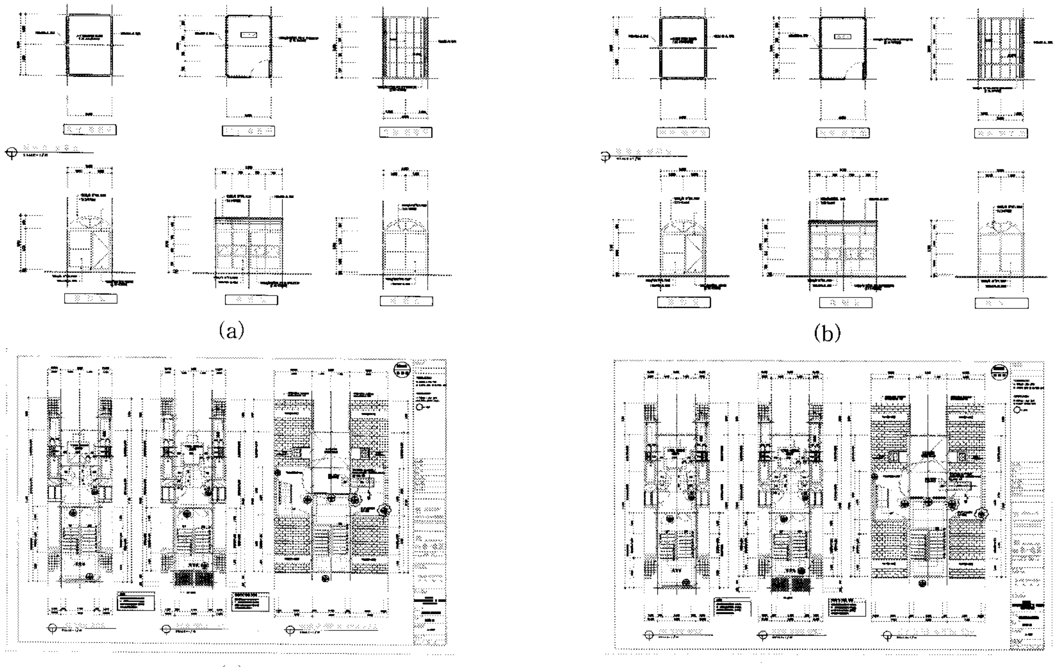
The correlation response is calculated by the similarity of the attacked watermark w_C^* and original watermark w.

$$Sim(w, w_C^*) = \frac{w \cdot w_C^*}{\sqrt{w_C^* \cdot w_C^*}} \tag{13}$$

4. EXPERIMENTAL RESULTS

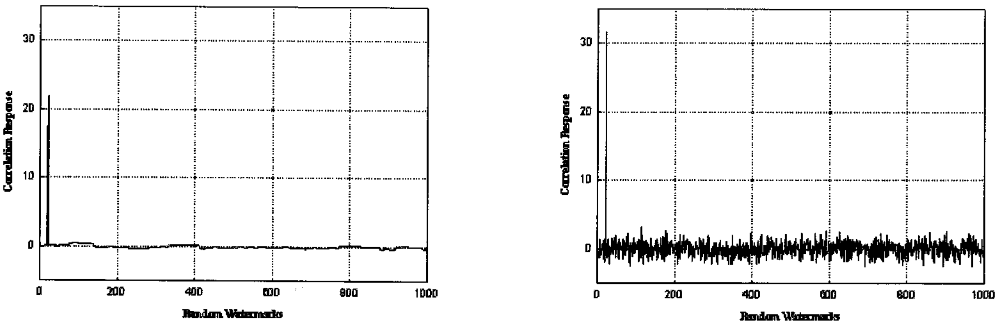
Our experiment used test architectural design drawings of *building external form drawing* and *Stair section-detail drawing* that are manufactured by AutoCAD 2002 tool. The key watermark was used as 20th seed in 1000 Gaussian random sequences and distortion indices α_L, α_A and α_C are 0.0001, 1.0 and 0.001 respectively for the transparency of watermark. For the convenience of experiments, we calculated D_n previously with 20th key watermark in line watermarking. Test drawings have different number of line, arc and circle. Therefore, we embedded the watermark with 916 length into 916 line components in *building external form drawing* and the watermark with 1000 length into 2227 arc components in *Stair section-detail drawing* and the watermark with 186 length into 186 circle components in *Each part detailed drawing*. There has not been developed benchmarks for evaluating the performance architectural drawing watermarking similar as stirmark. Therefore, our experiment performed the robustness evaluation with kinds of attack described in 2.2 subsection.

Fig. 7 shows original architectural drawings and



(a) (b) (c) (d)

Fig. 7. (a) original and (b) line watermarked *building external form drawing*, (c) original and (d) arc watermarked Stair section-detail drawing.



(a) (b)

Fig. 8. Correlation responses of (a) line watermarked building external form drawing, (b) arc watermarked Stair section-detail drawing, and (c) circle watermarked Each part detailed drawing.

watermarked architectural drawings and Fig. 8 shows correlation responses in watermarked architectural drawings. From figures 7 and 8, we know that the watermark can be embedded transparently in architectural drawings and also unique key value can be detected. The correlation response values of line, arc and circle are 21.93, 31.58, and 13.18. Each correlation responses are different because of the number of embedded watermark. Table 1 shows the correlation response in file format conversion attack. This experiment was performed by changing the watermarked architectural design drawing to another format that are available in other CAD tools. This table shows that there is no damage of all watermarks in lines, arcs and circles.

Fig. 9 (a) shows that each block from watermarked line drawing is moved to arbitrary position.

The watermark was not lost entirely though changing position of all blocks. The correlation responses are 21.93 in line watermarked drawing, 29.89 in arc watermarked drawing, and 13.18 in circle watermarked drawing. Fig. 9 (b) shows the watermarked arc drawing that is rotated to arbitrary direction. The correlation responses in line, arc, circle watermarked drawings are 21.93, 27.52 and 13.18 respectively. These results confirm that the watermarked drawings have the robustness against translation and rotation attacks. In scaling attack experiment, we confirm that the watermark in arc components can be detected correctly because the angle used as the embedding target has no effect on scaling attack. But in case of line or circle, we have to calculate correlation response after searching the scaling factor of scaled drawing. Table 2 shows the correlation response according to cropping ratio in line watermarked drawing. It could be seen that the correlation response decreases in proportion to cropping ratio but many of them are exist.

For more stable watermarking scheme, the watermark was embedded into all line, arc and circle

Table 1. The correlation responses for file format conversion.

Format	DXF	DWG	DWT	DWS
LINEs	21.93	21.93	21.93	21.93
ARCs	31.58	31.58	31.58	31.58
CIRCLEs	13.18	13.18	13.18	13.18

Table 2. Watermarks damage by cropping ratio in lines.

Correlation Response	Watermark number	Cropping ratio(%)
21.93	916	0
21.19	828	9.6
16.66	552	39.7
15.83	492	46.3
14.83	367	59.9
13.90	305	66.7

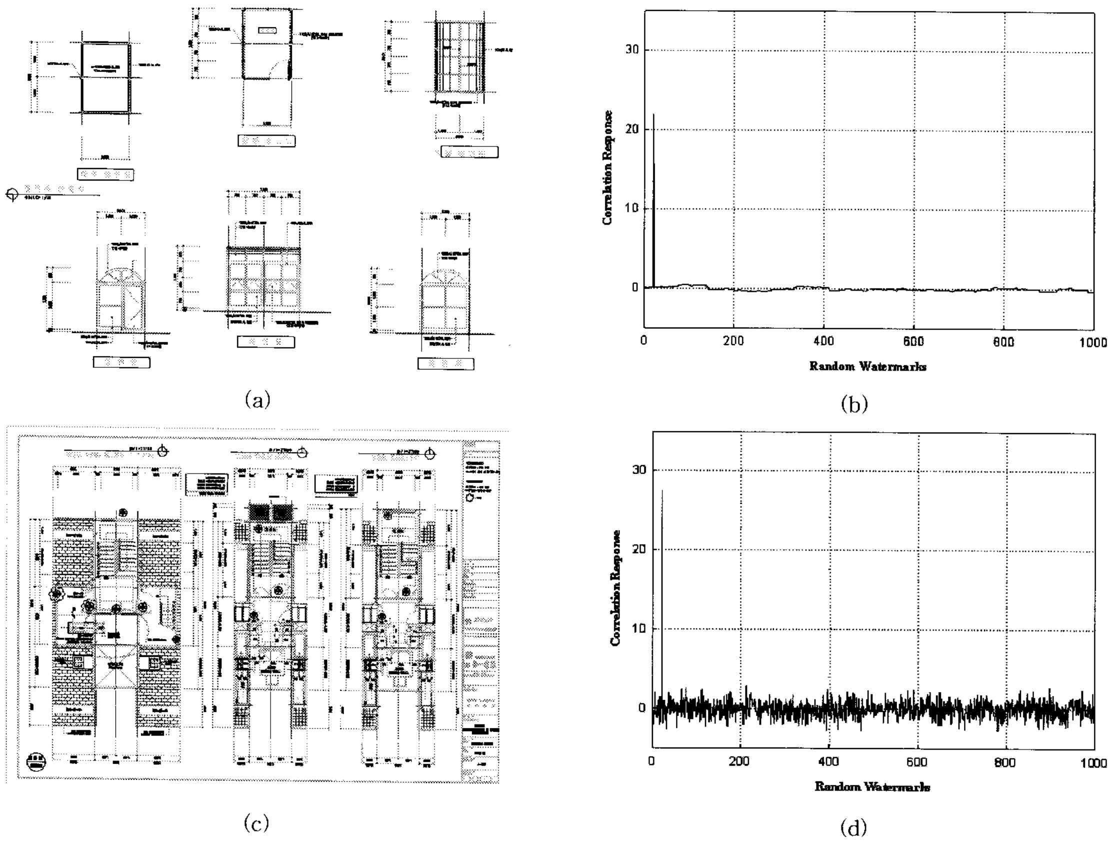


Fig. 9. (a) line watermarked building external form drawing with translation and (b) correlation response of (a), (c) arc watermarked Stair section-detail drawing with rotation and (d) correlation response of (c).

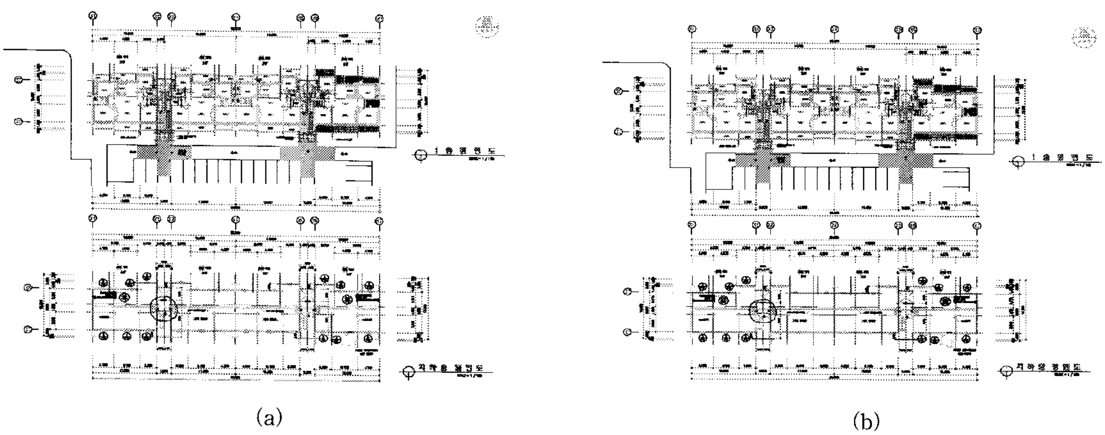


Fig. 10. (a) original design drawing and (b) line, arc and circle watermarked design drawing.

by using all proposed methods. Fig. 10 shows the whole watermarked drawing and Fig. 10 shows the magnified parts that the watermark is embedded. Table 3 show the robustness results against attacks. The Numbers of embedded watermark are each 1000 in line, 1000 in arc, 238 in circle. As

Table 3. Correlation response aboutg geometrical attacks in line, arc, and Cirlce watermarked drawing as shown in Fig. 10.

Attack		Correlation Response		
		LINE	ARC	CIRCLE
Translation		23.49	31.02	14.71
Rotation		23.49	27.63	14.71
Crop 50%		12.62	21.45	6.05
Scaling	enlarge	11.90	31.02	8.61
	reduce	10.72	31.02	8.71

shown in Table 3, the correlation responses of embedded watermark can be preserved to be high numerical value against most geometrical attacks.

5. CONCLUSIONS

In this paper, we proposed a robust watermarking algorithm in geometrical attacks using line, arc, and circle in architectural drawing. There are each different algorithm for each components. And also public(blind) watermarking that have secure detection algorithm is schemed in this method. In experiment result, perceptually artifact by watermarks embedded from proposed method did not recognize anyone, as confirmed before, we could know that watermark was showed robust characteristics under various kinds condition be regarded as geometrical or another attacks. These results can help to have copyright about building design technology is not protected by intellectual property entirely. As this, we expect that is going to ready minimum protection standard in copyright protection of exposed architectural design drawing shieldlessly. And we expect that may apply to watermarking for more 2-D image based on vertex.

REFERENCES

[1] I. J. Cox, J. Kilian, F. T. Leighton, and T. Shammon, "Secure Spread Spectrum for Watermarking for multimedia," *IEEE Trans. Image Processing,* Vol.6, pp. 1673-1687, 1997.

[2] Mitchell D. Swanson, Bin Zhu, and Ahmed H. Tewfik "Robust Data Hiding for Images," *Proc. of the IEEE Digital Signal Processing Workshop,* pp. 37-40, Sep. 1996.

[3] C. I. Podilchuk and W. Zeng, "Image Adaptive Watermarking using Visual Models," *IEEE Journal on Selected Areas in Communications,* Vol.16, No.4, pp. 525-539, May 1997.

[4] R. Ohbuchi, H. Masuda, and M. Aono, "Watermarking three-dimensional polygonal models through geometric and topological modification," *IEEE Journal on Selected Areas in Communications*, Vol.16, No.4, pp. 551-560, 1998.

[5] R. Ohbuchi, S. Takahashi, T. Miyazawa, and A. Mukaiyama, "Watermarking 3D Polygonal Meshes in the Mesh Spectral Domain," *Proc. of Graphics qInterface 2001*, pp. 9-17, 2001.

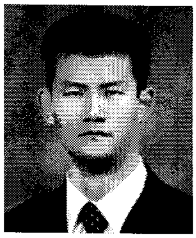
[6] O. Benedens, "Geometry-Based Watermarking of 3D Models," *IEEE Computer Graphics and Applications,* Vol.19, No.1, pp. 46-55, Jan./Feb. 1999.

[7] S.-H. Lee and K.-R. Kwon, "A Watermarking for 3D-Mesh Using the Patch CEGIs," *Digital Signal Processing*, Vol.17, Issue 2, pp. 396-413, March 2007.

[8] R. Ohbuchi, Hiroo Ueda, and Shuh Endoh, "Robust Watermarking of Vector Digital Maps," *ICME2002,* Aug. 2002.

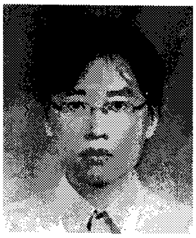
[9] K.-R. Kwon, S.-H. Lee, E.-J. Lee, and S.-G. Kwon, "Watermarking for 3D CAD Drawings Based on Three Components," *Lecture Note*

in Computer Science by Springer verlag, Vol. 4109/2006, pp. 217-225, Oct. 2006.



Bong-Joo Jang

Bong-Joo Jang received the B.S., M.S. degrees in electronics & Compute engineering from Pusan University of Foreign Studies in 2002, 2004. He joined the Pukyong National University for doctor's degree in 2007. His current research interests are in the area of digital image/video processing, watermarking and embedded system design.



Suk-Hwan Lee

He received a B.S., a M.S., and a Ph. D. degree in Electrical Engineering from Kyungpook National University, Korea in 1999, 2001, and 2004 respectively. He is currently an assistant professor in department of Information Security at Tongmyong University. His research interests include multimedia security, digital image processing, and computer graphics.

Ki-Ryong Kwon

Ki-Ryong Kwon received the B.S., M.S., and Ph.D. degrees in electronics engineering from Kyungpook National University in 1986, 1990, and 1994 respectively. He worked at Hyundai Motor Company from 1986-1988 and at Pusan University of Foreign Language from 1996-2006. In 2006, he joined the Pukyong National University, where he is an professor. His current research interests are in the area of digital image processing, multimedia security and watermarking, wavelet transform.

Kwang-Seok Moon

Kwang-Seok Moon received the B.S., M.S., and Ph.D. degrees in electronics engineering from Kyungpook National University in 1979, 1981, and 1989 respectively. He is currently a professor in Division of Elec. Computer, and Telecomm. Eng. at Pukyong National University since 1990. His current research interests are in the area of digital image processing, video watermarking, and multimedia communication.