

Digital Watermarking Algorithms for Visible Watermarks

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ABSTRACT

Imposing one signal on another signal is termed modulation and is very common in electronic communication. Imposing one image on another image is termed watermarking. Digital watermarking is the hiding of a visible or secret message or information (watermark) within an ordinary message (host). Digital watermarking is applied for copyright protection, content authentication, detection of illegal duplication and alteration, feature tagging and secret communication. For reasons of environmental protection and energy conservation, people are adopting paperless records and documents. e-documents are replacing paper documents. Five digital watermarking algorithms were developed and applied for placement of visible watermarks as e-signature, e-stamp, e-logo, e-label, and e-copyright on e-document images, medical images, and other images. Necessary mathematical equations were formulated for the algorithms. Tuning parameters are used to regulate the location of watermark on host image and adjust the amplitude of the watermark relative to the amplitude of the host. The algorithms deployed e-signature, e-stamp, e-logo, e-label and e-copyright satisfactorily on host images.

Keywords: Visible Watermarks, e-signature, e-stamp, e-logo, e-label, e-copyright.

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I. INTRODUCTION

Imposing one signal on another signal is termed modulation and is very common in electronic communication. Modulation is the systematic variation of a property of one signal called the carrier in accordance to the instantaneous amplitude of another signal called the baseband signal or the information bearing signal or the modulating signal [1]. Actually, the carrier is just being used to carry the other signal across the communication channel. The property of the carrier being varied may be the amplitude, frequency or phase which give rise to Amplitude Modulation technique (AM), Frequency Modulation technique (FM) or Phase Modulation technique (PM) respectively. There are digital modulation techniques like Pulse Amplitude Modulation (PAM),

Delta Modulation (DM) and Pulse Code Modulation (PCM). Electronic communication is the transfer of information from one point to another by electronic means. Fig. 1 shows the block diagram of a typical electronic communication system [1]. The information is usually converted to an electronic signal.

Modulation is necessary in electronic communication to enable the information bearing signal travel long distance through the channel and to permit multiplexing. Multiplexing is the transfer of different information signals over a single channel. Some property of the carrier signal S2 is varied in accordance with S1 to give the modulated signal S3 which is transmitted over the channel. S1 is recovered at the receiving end.

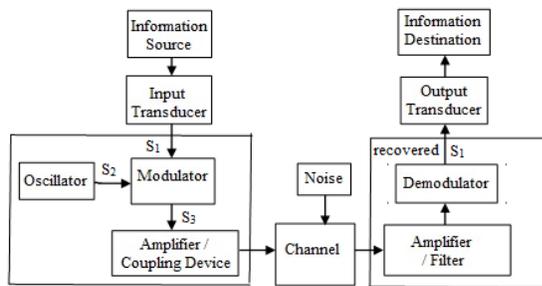


Fig. 1: Sampling of analog signal and loss of samples [1].

Modulation is deliberate interference of one signal with another. Two (or more) signals are mixed together at the sending end. One signal is interfering with another signal. But the concept of “desired signal” and “unwanted signal (noise)” is somehow complicated here. One man’s food is another man’s poison. Anyway, successful separation and recovery of all the signals or at least the desired signal at the receiving end is desirable.

The rapid expansion of the internet and the increased availability of digital data recording and duplicating devices have increased the availability of digital data (such as text, audio, images, and videos to the public [2,3,4,5]. Copyright owners are concerned about illegal duplication and distribution of their data and work. A solution for this is to use digital watermarking to protect the intellectual property of creators, distributors or owners of such data.

Digital watermarking is applied for copyright protection, content authentication, detection of illegal duplication and alteration, feature tagging and secret communication. Digital watermarking is the hiding of a visible or secret message or information (watermark) within an ordinary message (host) and its extraction at its destination. The use of watermarks is as old as paper manufacturing [6,7]. Watermarking is first used in paper mills as paper mark of the company [8]. Watermarking was later introduced in postage stamps and national currency notes to make forgery more difficult [6,8].

The digitization of our world expanded the concept of watermarking to include immaterial digital impressions for use in authenticating ownership claims and protecting proprietary interests [6]. Digital watermarks are like their ancestors (paper watermarks) [6]. Digital watermarking is an active area of research [9,10,11,12,13,14,15,16,17, 18,19,20,21,22]. Tao, Chongmin, Zain and Abdallah

(2014) did a thorough review of Robust Image Watermarking Theories and Techniques [20].

A visible watermarking scheme has two conflicting requirements which are visibility and unobtrusiveness [21]. It’s expected to be visible and it’s expected not to cover vital image details. At times, it’s good if it’s translucence. A secret watermarking scheme has three requirements which are imperceptibility, robustness, and capacity [9,10,12,15].

A Model for Watermarking and Secret Communication is presented in Fig. 2 and is described by Eqn. (1) [9,10,12,14,15,20,21]. Like modulation, watermarking involves embedding one image signal known as the watermark (w) in another image signal known as the host (h) to form watermarked image (g). w constitutes noise in h . C_1 and C_2 are weighting factors [21]. Watermark extraction is required to detect the presence of w in g and recover both h and w from g . Intentional addition of one image to another image for the purpose of Watermarking (ownership identification) and Secret Communication may have adverse effects on both images.

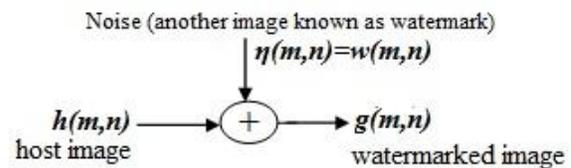


Fig. 2: Model for Watermarking and Secret Communication [9,12,15].

$$g(m, n) = C_1 h(m, n) + C_2 w(m, n) \quad (1)$$

For reasons of environmental protection, energy conservation, space conservation and running cost reduction, people and establishments are adopting paperless records and documents. e-documents are replacing paper documents. In this work, five algorithms were developed for application of digital watermarking of visible watermarks as e-signature, e-stamp, e-label, and e-copyright on e-document images, medical images and other images based on the model of Fig. 2 and Eqn. (1). Necessary mathematical equations were formulated for the algorithms. These arithmetic and logical equations represent the means of effecting or implementing the watermarking basic Eqn. (1) for the specific applications. Users can specify the location of watermark on the host image. Certain tuning parameters are introduced to guide the process and also to ensure that the watermark does not

cover vital information in host image. The watermarking procedures or steps are described in the following section with the aid of block diagrams and the formulated mathematical equations.

II. DIGITAL WATERMARKING ALGORITHMS

2.1 e-signature

The proposed e-signature watermarking process is shown in Fig. 3. t , x , y , and T are constants which can be regarded as tuning parameters. These tuning parameters are used to regulate the location of watermark on host image and adjust the amplitude of the watermark relative to the amplitude of the host.

The e-signature w is first pre-processed to ensure it's on a pure white background. w_p is the pre-processed watermark and is given by Eqn. (2). The objective of pre-processing is to improve the contrast of the signature compared with the background. w_p is set equal to w . Then, any pixel in the w_p such that its red (r), green (g) and blue (b) components are greater than the threshold t is considered to belong to the background and is made white by changing its r , g and b components to 255 as described in Eqn. (2).

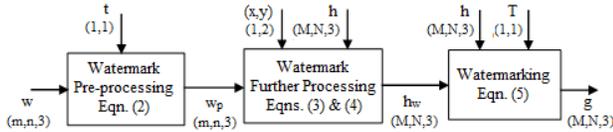


Fig. 3: e-signature watermarking process.

$$w_p(i, j, k) = \begin{cases} 255 & \text{if } w(i, j, 1) > t \text{ \& } w(i, j, 2) > t \\ & \text{\& } w(i, j, 3) > t \\ w(i, j, k) & \text{otherwise} \end{cases} \quad (2)$$

Fig. 4 which shows the r , g and b colour components for some grey levels. As r , g and b tend to 255, the colour tends to white. As r , g and b tend to 0, the colour tends to black. For example, $w(i,j,1)$, $w(i,j,2)$ and $w(i,j,3)$ in Eqn. (2) are the r , g and b components of w . A threshold t was introduced to distinguish the signature from the background. If a pixel appears to be close to white ($180 \leq r$, g and $b \leq 255$), it's treated as background and all its colour components are set to 255 as in Eqn. (2). Otherwise, the pixel is treated as part of the signature and its r , g and b values are left intact as in Eqn. (2).

The dimensions of h and w are obtained as M by N by 3 and m by n by 3 respectively: $M > m$ and $N > n$. A blank white image h_b of the same dimension as h is formed as given by Eqn. (3). The user supplies and can change a starting pixel coordinate (x,y) location for the placement of the e-signature on the host. The e-signature is placed on h_b to form h_w in accordance with Eqn. (4). The watermarked image g is obtained from h and h_w by Eqn. (5) such that any white pixel in h_w (with r , g and b components greater than threshold T) is replaced with corresponding host image pixel. h_w has some part containing watermark information and the remaining part is blank or white. Host information is to be added to the white part of h_w . Threshold T is used to identify the white part. If a pixel in h_w appears to be white ($240 \leq r$, g and $b \leq 255$), it's treated as white and is replaced by corresponding host pixel as in Eqn. (5). For multiple e-signatures, a watermarked image with e-signature is resented as host h and the process is repeated.

Colour Components	Grey Level	0	30	60	90	120	150	180	210	240	255
r		0	30	60	90	120	150	180	210	240	255
g		0	30	60	90	120	150	180	210	240	255
b		0	30	60	90	120	150	180	210	240	255

Fig. 4: Some grey levels obtainable with red-green-blue (rgb) colour model.

$$h_b(i, j, k) = 255 \quad (3)$$

$$h_w(i, j, k) = \begin{cases} w_p(i-x+1, j-y+1, k) & \text{if } x < i < (x+m-1) \\ & \text{\& } y < j < (y+n-1) \\ h_b(i, j, k) & \text{otherwise} \end{cases} \quad (4)$$

$$g(i, j, k) = \begin{cases} h(i, j, k) & \text{if } h_w(i, j, 1) > T \text{ \& } h_w(i, j, 2) > T \\ & \text{\& } h_w(i, j, 3) > T \\ h_w(i, j, k) & \text{otherwise} \end{cases} \quad (5)$$

2.2 e-stamp or e-logo

The proposed e-stamp or e-logo watermarking process is presented in Fig. 5. x , y , and T are constants which can be regarded as tuning parameters. The e-stamp or e-logo w is first pre-processed. The pre-processing involves flipping the e-stamp or e-logo from right to left if required. In some cases, this may not be required. The dimensions of h and w are obtained as M by N by 3 and m by n by 3 respectively: $M > m$ and $N > n$. A blank white image h_b of the same dimension as h is formed as given by Eqn. (3). The user supplies and can change a starting pixel

coordinate (x,y) location for the placement of the e-stamp or e-logo on the host.

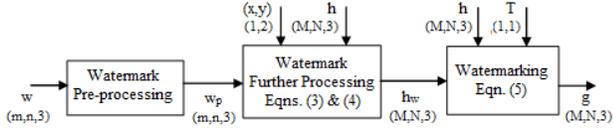


Fig. 5: e-stamp or e-logo watermarking process.

The e-stamp or e-logo is placed on h_b to form h_w in accordance with Eqn. (4). The watermarked image g is obtained from h and h_w by Eqn. (5). A typical value of threshold T is in the range [240-255] as discussed in section 2.1. For multiple e-stamp, a watermarked image with e-stamp is resented as host h and the process is repeated.

2.3 e-label on medical images

e-label on medical images may contain information like patient's surname, hospital number and the date the medical image was captured. The proposed e-label on medical image watermarking process is exactly like e-stamp watermarking process discussed in section 2.2 and illustrated in Fig. 5. The pre-processing involves flipping the transpose of the e-label from right to left if required. This may be necessary to ensure that critical medical information on the medical image is not covered by the e-label. This may not be required in some cases.

2.4 Background e-stamp or e-logo

In some cases, the host image which is an e-document is black write up on white background. Part of the white background can be replaced with a visible e-stamp or e-logo at the center by watermarking. Background e-stamp or e-logo watermarking process is illustrated in Fig. 6. c , T , and τ are constants which can be regarded as tuning parameters. The pre-processing involves flipping the e-stamp or e-logo from right to left if required. In some cases, this may not be required.

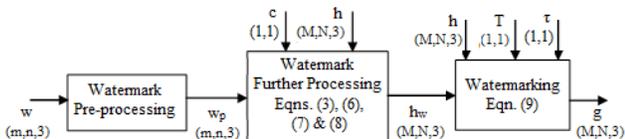


Fig. 6: Background e-stamp or e-logo watermarking process.

The dimensions of h and w are obtained as M by N by 3 and m by n by 3 respectively: $M > m$ and $N > n$. A blank

white image h_b of same dimension as h is formed as given by Eqn. (3). The starting pixel coordinate (x,y) location for the placement of the e-stamp or e-logo on the host is obtained by Eqns. (6) and (7). The e-stamp or e-logo w with a scaling constant c is placed at the center of h_b to form h_w in accordance with Eqn. (8). c is to ensure that the e-stamp or e-logo is just slightly visible in the background. c ranges from 1 to 1.5.

$$x = \frac{M}{2} \left\lfloor \text{approximated to the lowest whole number} \right\rfloor - \frac{m}{2} \left\lfloor \text{approximated to the lowest whole number} \right\rfloor - 1 \quad (6)$$

$$y = \frac{N}{2} \left\lfloor \text{approximated to the lowest whole number} \right\rfloor - \frac{n}{2} \left\lfloor \text{approximated to the lowest whole number} \right\rfloor - 1 \quad (7)$$

The watermarked image g is obtained from h and h_w by Eqn. (9). Threshold T first identify a pixel in h which is part of the write up on e-document if its r , g and $b \leq T$; where $150 < T < 220$. Such identified pixel must appear in the watermarked image and a value of τ is deducted from its r , g and b values to make it darker as in Eqn. (9). τ is in the range [0-30]. Subtracting a constant τ from the r , g and b values make the pixel closer to black as illustrated in Fig. 4. The user may override Eqns. (6) and (7) by supplying a starting pixel coordinate (x,y) location for the placement of the e-stamp on the host.

$$h_w(i, j, k) = \begin{cases} cw_p(i - x + 1, j - y + 1, k) & \text{if } x < i < (x + m - 1) \\ & \text{\& if } y < j < (y + n - 1) \\ h_b(i, j, k) & \text{otherwise} \end{cases} \quad (8)$$

$$g(i, j, k) = \begin{cases} h(i, j, k) - \tau & \text{if } h(i, j, 1) < T \text{ \& if } h(i, j, 2) < T \\ & \text{\& if } h(i, j, 3) < T \\ h_w(i, j, k) & \text{otherwise} \end{cases} \quad (9)$$

2.5 e-copyright

The proposed e-copyright watermarking process for adding visible watermark w as e-copyright to a host image h is shown in Fig. 7. x , y , and c are the tuning parameters. The dimensions of h and w are obtained as M by N by 3 and m by n by 3 respectively: $M > m$ and $N > n$. A dark image h_d of the same dimension as h is formed as given by Eqn. (10). The user supplies and can change a starting

pixel coordinate (x,y) location for the placement of the watermark on the host. The watermark is placed on h_d to form h_w in accordance with Eqn. (11). The watermarked image g is obtained from h and h_w by Eqn. (12). c is to reduce the intensity of e-copyright relative to the host image. c ranges from 0.1 to 0.5.

$$h_d(i, j, k) = 0 \quad (10)$$

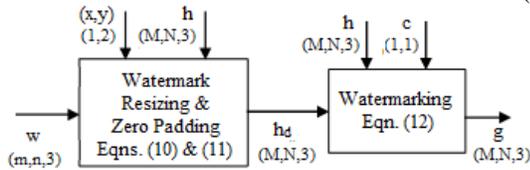


Fig. 7: e-copyright on image watermarking process.

$$h_w(i, j, k) = \begin{cases} w(i-x+1, j-y+1, k) & \text{if } x < i < (x+m-1) \\ & \text{\& if } y < j < (y+n-1) \\ h_d(i, j, k) & \text{otherwise} \end{cases} \quad (11)$$

$$g(i, j, k) = h(i, j, k) + ch_w(i, j, k) \quad (12)$$

III. RESULTS AND DISCUSSIONS

The processes were developed into algorithms in Matlab working environment. The algorithms are tested with some watermarks and host images. Test results are presented and discussed in this section. Possible ranges of the tuning parameters have been stated in section 2 but the values of the tuning parameters actually used for each test are recorded and presented with the results.

3.1 e-signature

The algorithm for the e-signature watermarking process was tested with e-signatures. The results are presented in Figs. 8, 9 and 10. e-signatures were successfully placed at specified locations on e-documents. Multiple e-signatures on a single e-document were achieved by re-sending a watermarked image as host and repeating the watermarking process with a different e-signature at a different location on the e-document.

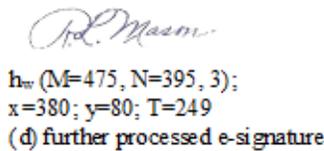
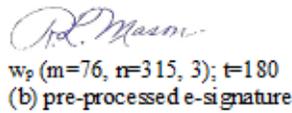
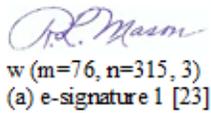


Fig. 8: e-signature on e-document first experimental results.

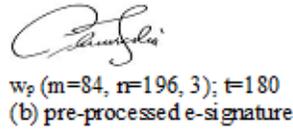
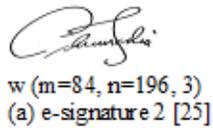


Fig. 9: e-signature on e-document second experimental results.

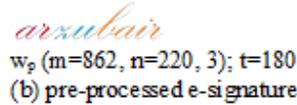
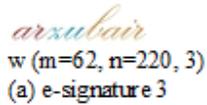


Fig. 10: e-signature on e-document third experimental results.

3.2 e-stamp or e-logo

The algorithm for the e-stamp or e-logo watermarking process was tested with e-stamps and e-logos. The results are presented in Figs. 11, 12, 13 and 14. e-stamps and e-logos were successfully placed at specified locations on e-

documents. Multiple e-stamps and or e-logos on a single e-document were achieved by re-sending a watermarked image as host and repeating the watermarking process with a different e-stamp or e-logo at a different location on the e-document.

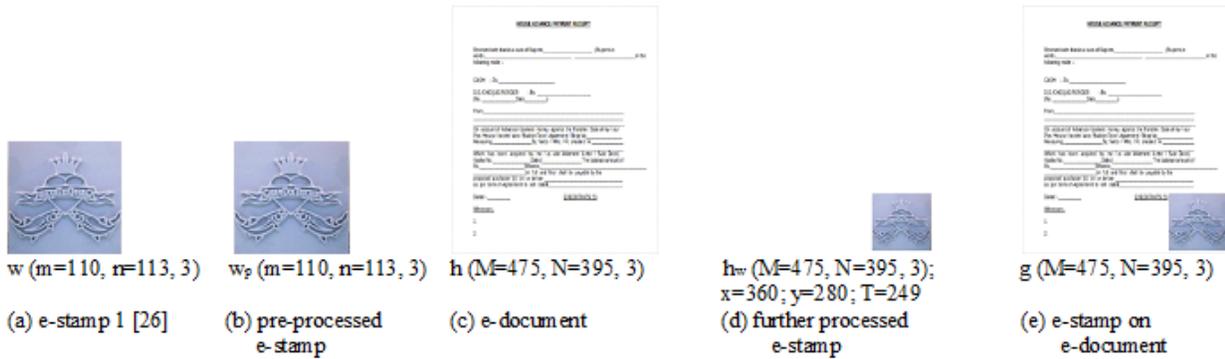


Fig. 11: e-stamp on e-document first experimental results.

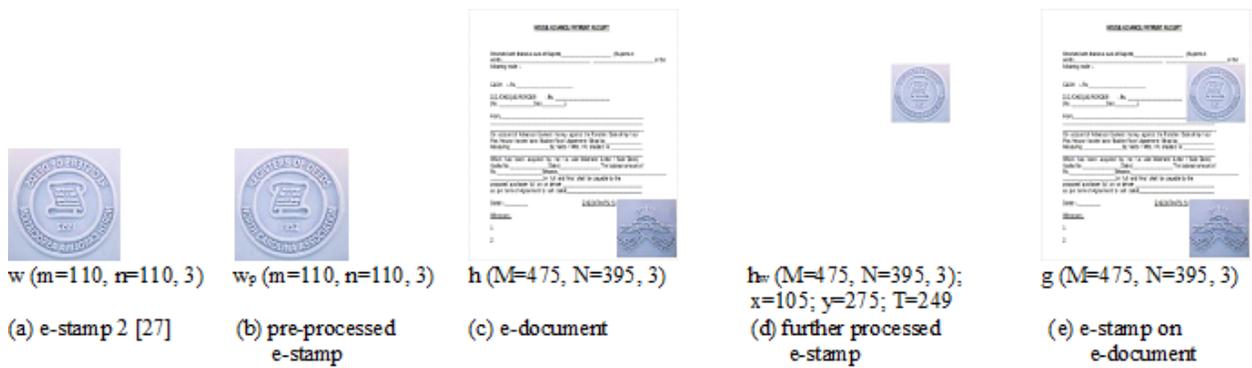


Fig. 12: e-stamp on e-document second experimental results.

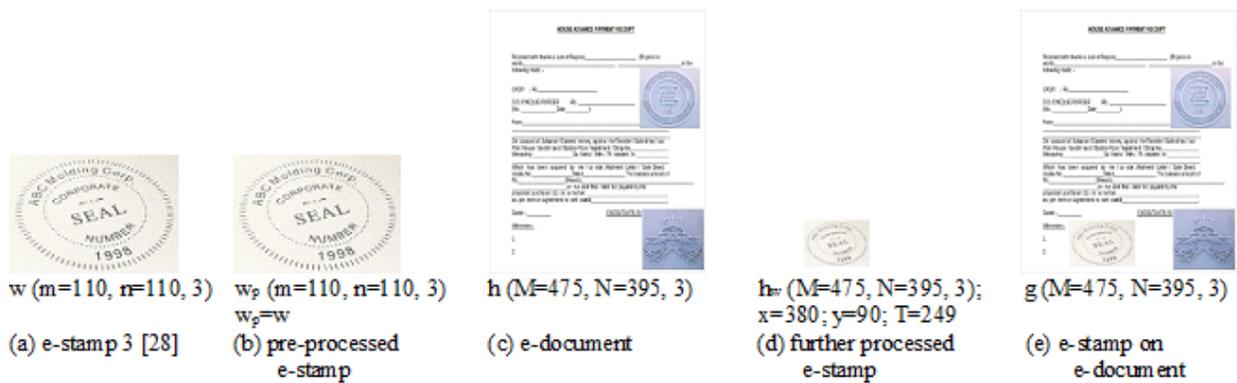


Fig. 13: e-stamp on e-document third experimental results.

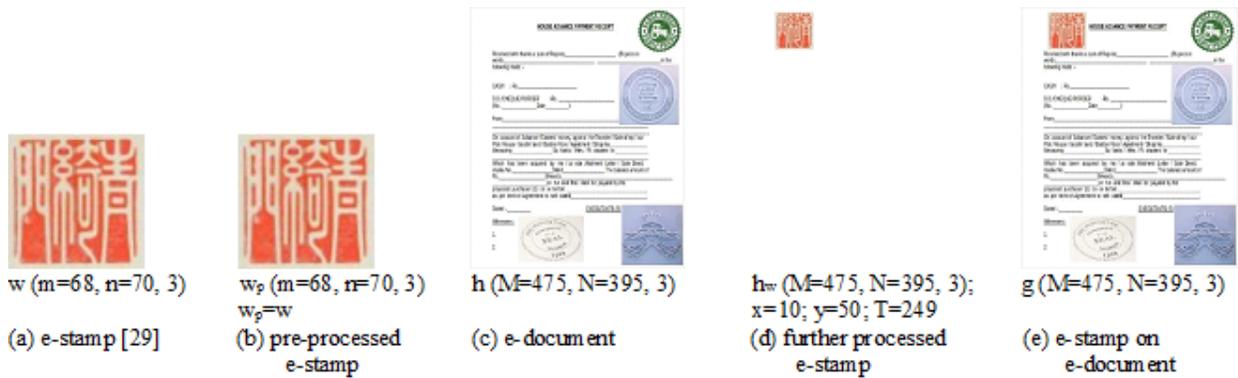


Fig. 14: e-stamp on e-document fourth experimental results.

3.3 e-label on medical image

The algorithm for the e-label watermarking process was tested with three e-labels and medical images. The results are presented in Figs. 15, 16 and 17. e-labels were

successfully placed at specified locations on medical images.

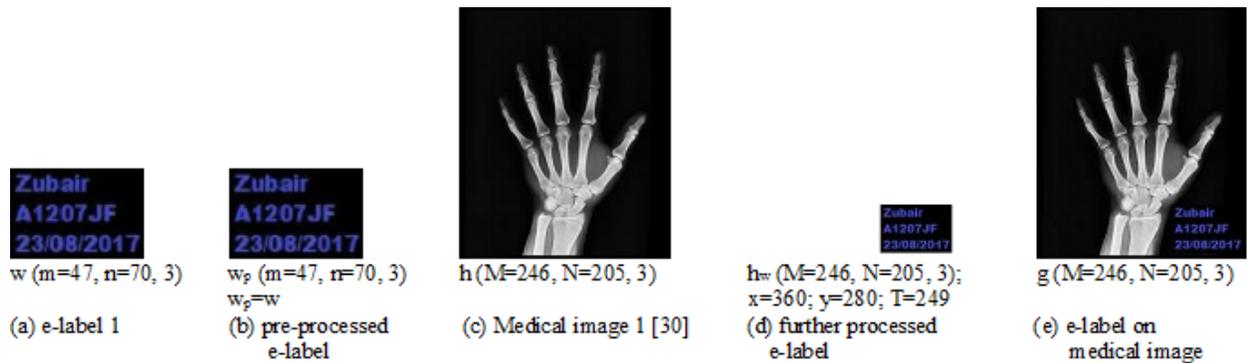


Fig. 15: e-label on medical image first experimental results.

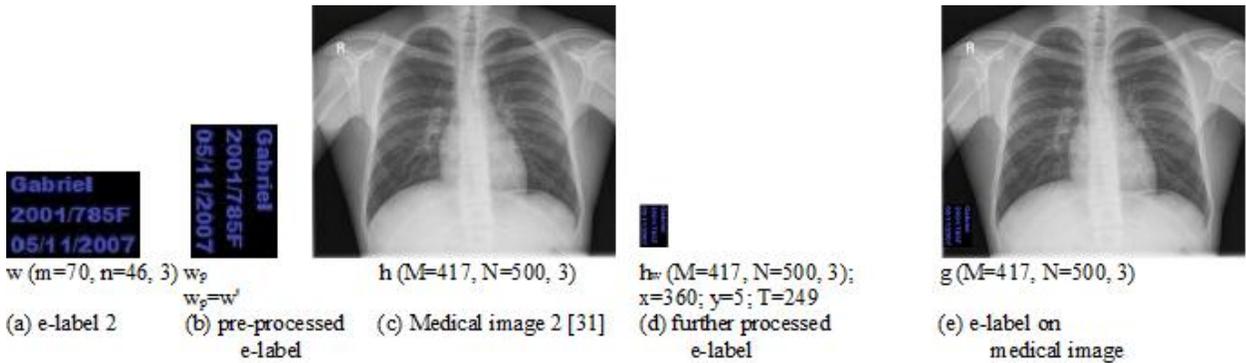


Fig. 16: e-label on medical image second experimental results.

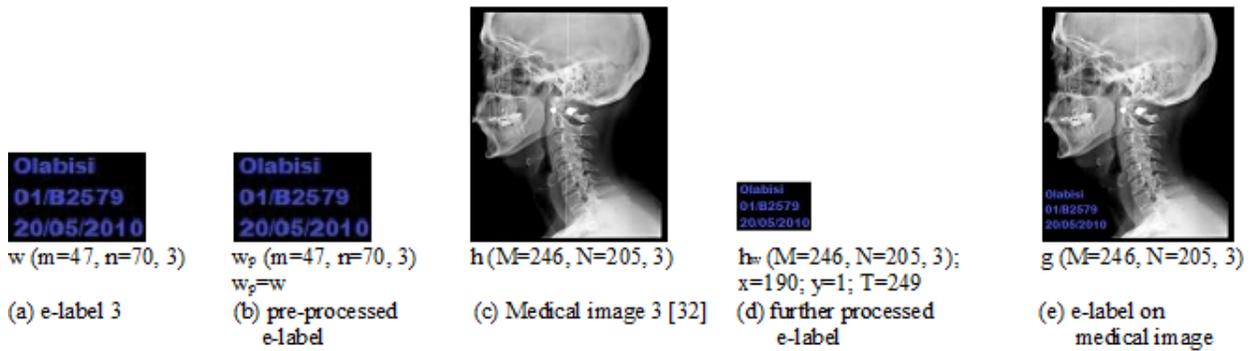


Fig. 17: e-label on medical image third experimental results.

3.4 Background e-stamp or e-logo

The algorithm for the background e-stamp watermarking process was tested with e-stamps or e-logos. The results are presented in Figs. 18, 19 and 20. e-stamps were successfully placed as the background images at specified

locations on e-documents. It is observed from the displayed results that the higher the value of parameter c , the lighter is the background logo. Furthermore, the higher the parameter τ the clearer the e-document black write-up against the background e-logo.

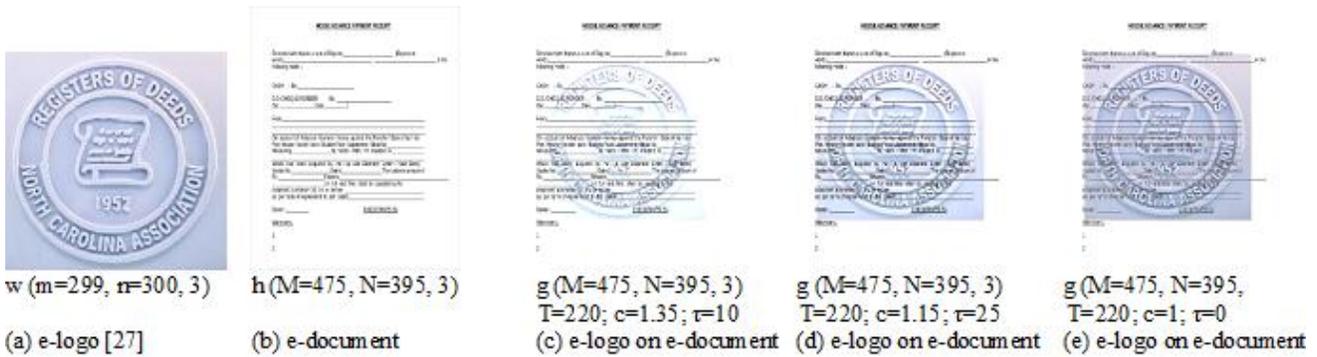


Fig. 18: Background e-logo on e-document first experimental results.

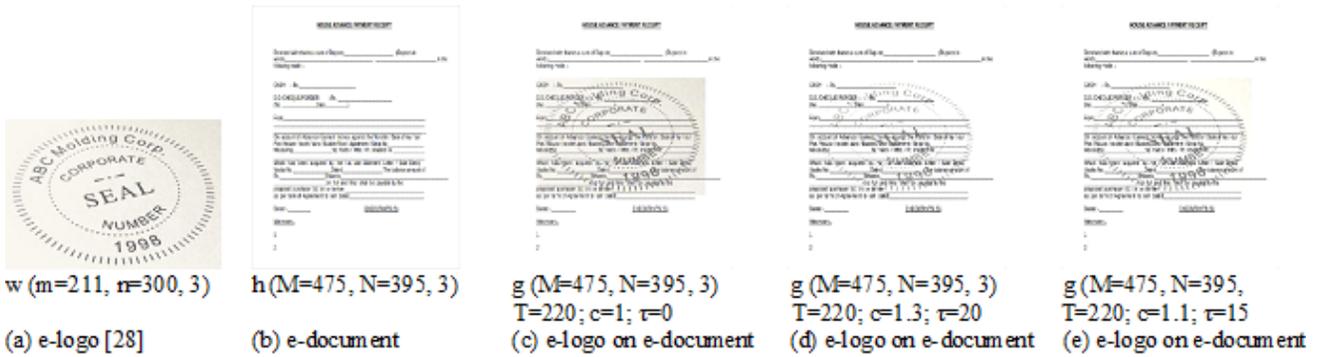


Fig. 19: Background e-logo on e-document second experimental results.

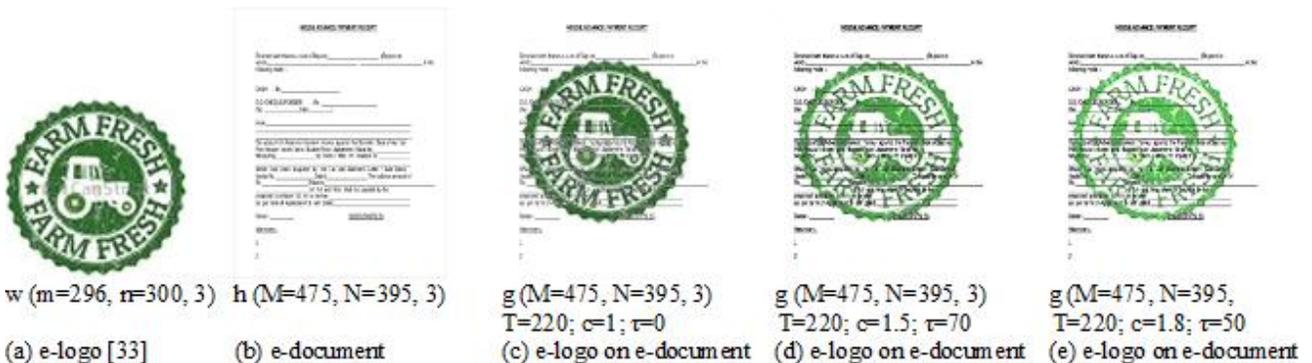


Fig. 20: Background e-logo on e-document third experimental results.

3.5 e-copyright on images

The algorithm for the embedding of visible watermark as e-copyright on a host image was tested. The results are

presented in Figs. 21, 22 and 23. Visible watermarks were successfully placed at specified locations as e-copyright on host images.



Fig. 21: Visible watermark as e-copyright on host image first experimental results.

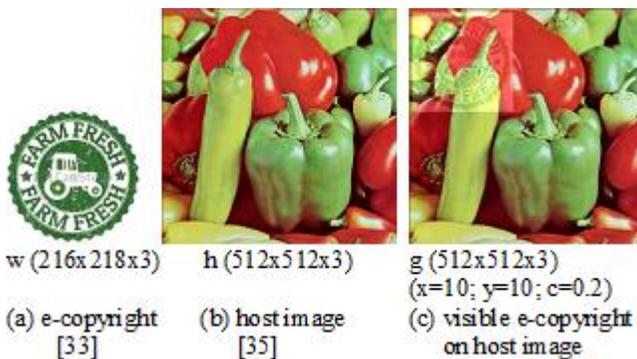


Fig. 22: Visible watermark as e-copyright on host image second experimental results.

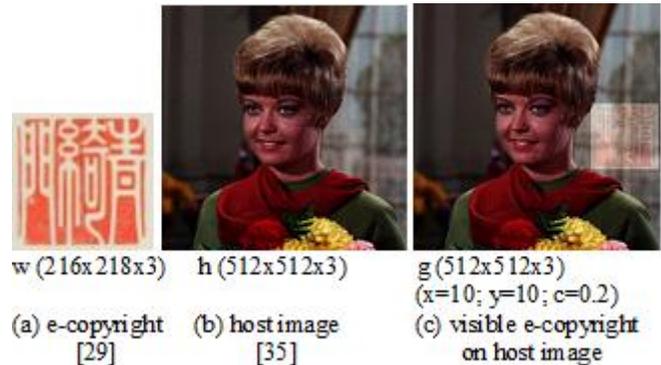


Fig. 23: Visible watermark as e-copyright on host image third experimental results.

IV. CONCLUSIONS

Algorithms for the deployment of watermarks as e-copyright, e-signature, e-stamp, e-logo and e-label on e-document images, medical images and general images have been developed. E-signature, e-stamp, e-logo, e-label, and e-copyright were successfully placed at specified locations on host images. Multiple watermarks on a single host image are also realized. Tuning parameters were introduced to regulate the location of watermark on host image and adjust the amplitude of the watermark relative to the amplitude of the host.

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