Fuzzy Logic based watermarking using non – blind HVS technique

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Abstract - *This article proposes a non-blind water-marking based on Human Visual System (HVS) and Fuzzy Inference System (FIS) with Discrete Cosine transform (DCT). The image transformed is segmented into 8 × 8 non over-lapping blocks and for each block parameters such as contrast sensitivity, luminous sensitivity, edge sensitivity, number of on pixels and number of regions are designed and are fed to FIS. The output of fuzzy system is a single value which gives a continuous value of analogous to each DCT coincident. A binary watermark is set in the original image based on perpetual weight premeditated through FIS. The robustness of proposed method is examined by subjecting watermarked image to several attacks. It is institute that fuzzy based watermarking achieves high imperceptibility and robustness to attacks.*

Key Words: **HVS, FIS, DCT**

1.INTRODUCTION

With the increase in the availability of digital data over internet, the images so distributed can be copied repeatedly with or without error, putting the rights of owner at risk. One way to arrest illegal duplication is to in-sert owner's identity known as watermark into potentially vulnerable images so that watermarks are inseparable from the images itself. The important requirements of watermarking [1] are centered on three main issues -These are imperceptible quality of watermarked and attacked images, robustness and embedding capacity. Among these the former two parameters are important and these are found to be mutually conflicting. Because of this water-marking may be perceived as an optimization problem to obtain robust embedding and extraction scheme. This paper addresses the problem by constructing fuzzy perpet-ual masks. Human Visual System is the ultimate receiver of most processed images. Incorporating. Just Noticeable Difference (JND) provides a means to model perpetual redundancy that is the maximum distortion which cannot be perceived by human eye. In [6]-[8] JND thresholds are computed based on background luminance adaption and spatial contrast masking. In [2] a more accurate JND map is deduced considering the overlapping effect between luminous adaption and spatial contrast masking. But the drawback of the scheme is it does not consider contrast sensitivity function.A brief introduction of fuzzy logic is provided in section II. Proposed watermark embeding and extraction algorithms are presented in section III. Simulation results are presented in section IV. Conclusions are provided is in section V

2. FUZZY LOGIC

Fuzzy logic provides a means for incorporating human knowledge in the solution of problems whose formulation is based on vague concepts [1]. FIS is used to map a given input to output based on fuzzy logic. Unlike crisp sets, fuzzy sets are having infinite valued membership functions. The mapping then provides a framework for interpreting the data from which decisions can be made.

Principles of Fuzzy set theory: Let Z is a set of elements with element of Z denoted by z. This set is called Universe of Discourse. A fuzzy set A in Z is denoted by $\mu_A(Z)$ that associates each element with an interval between [0, 1].Therefore a fuzzy set is an ordered pair consists of values of z and a membership function that assigns a grade of membership to each z.

The FIS has the following blocks as given in Ref. [2].

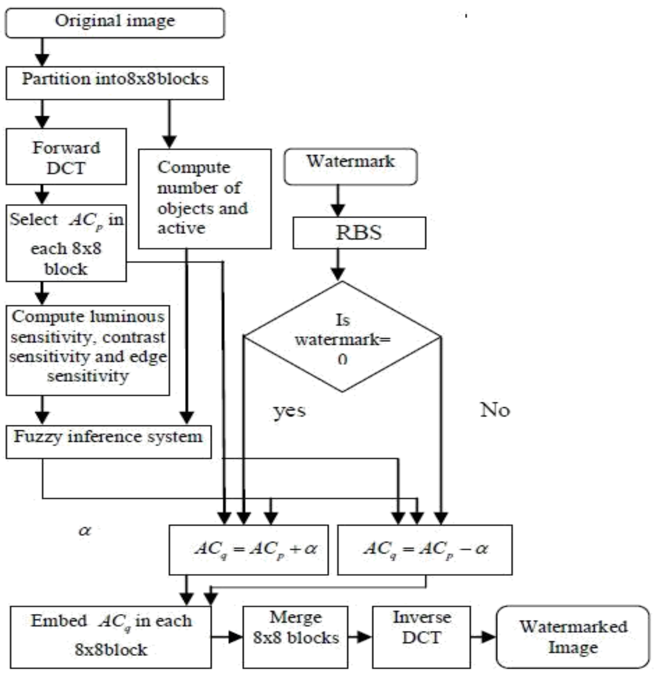
- **Fuzzification:** for each scalar input, find the corre-sponding fuzzy values by mapping the input to the interval [0, 1], using applicable rules defined in rule editor.
- **Apply an implication method**: It is way to use inputs and the knowledge base represented by if-then rules to creates the output of system. This process is known as implication or inference.

- **Defuzzification**; Final step is converting fuzzy output to crisp output by computing the center of gravity of aggregated fuzzy set.

$$v0 = \frac{\sum_{i=1}^{n} iQ(i)}{\sum_{i=1}^{n} i} \qquad (1)$$

3. PROPOSED ALGORITHM

The proposed watermarking is a non-blind watermark-ing based on Fuzzy logic. The input parameters fed to FIS are contrast sensitivity, luminous sensitivity, edge sensitivity, number of objects, Number of active pixels.



3.1. WATERMARK EMBEDDING ALGORITHM

The watermark concealing algorithm is given in the following steps in fig.1:

1) Take original image of size 256 × 256 is taken and segment it into 8 × 8 blocks and compute number of on pixels and number of regions and apply DCT and compute luminous sensitivity, edge sensitivity and contrast sensitivity.

a) Luminous sensitivity : If the background is brighter, more information can be hidden in original image [3] without noticing distortion. Luminous sensitivity is measure of brightness of back ground. In each block the first element (0, 0) represent DC component of block and X_{DCM} is the mean of all D.C. coefficients of 8 × 8. It is defined in Eqn.2.

$$Luminous\ sensitivity = \frac{X_{DC,i}}{X_{DCM}} \qquad (2)$$

b) Contrast sensitivity: Watermark embedded in textured region is harder to notice compared to smooth regions. The contrast sensitivity is measured by computing variance in each block using the matlab command “statxure ”. Where image_seg is 8 × 8 block of image and C is the second element of 7 row vector generated by this command.This parameter is obtained by Eqn 3

$$C = statxture(image\_seg) \qquad (3)$$

c) Edge sensitivity: Watermark embedded in edge regions are harder to perceive compared to smoother region. The edges are detected by matlab command

$$j = graythresh(image\_seg) \qquad (4)$$

d) Number of on pixels: In Ref. [5] a pixel is said to be active if it has intensity less than mean value by a factor of where K(σ) where σ is taken 1.2.

e) Number of Regions: In Ref [5] it is calculated by converting image into binary image and count-ing the number of regions of connected pixels.

Rules used in Fuzzy inference system

i) If (luminous sensitivity is dark) and (contrast sensitivity is low) and (edge sensitivity is small) then (weight is least) (1)
ii) If (luminous sensitivity is dark) and (contrast sensitivity is medium) and (edge sensitivity is low) then (weight is least) (1)
iii) If (luminous sensitivity is dark) and (contrast sensitivity is high) and (edge sensitivity is low) then (weight is least) (1)
iv) If (luminous sensitivity is medium) and (contrast sensitivity is low) and (edge sensitivity is low) then (weight is least) (1)

v) If (luminous sensitivity is medium) and (contrast sensitivity is medium) and (edge sensitivity is low) then (weight is least) (1)
vi) If (luminous sensitivity is medium) and (contrast sensitivity is high) and (edge sensitivity is low) then (weight is least) (1)
vii) If (luminous sensitivity is bright) and (contrast sensitivity is low) and (edge sensitivity is low) then (weight is least) (1)
viii) If (luminous sensitivity is bright) and (contrast sensitivity is medium) and (edge sensitivity is low) then (weight is least) (1)
ix) If (luminous sensitivity is bright) and (contrast sensitivity is high) and (edge sensitivity is low then (weight is least) (1)
x) If (luminous sensitivity is dark) and (con-trast sensitivity is low) and (edge sensitivity is medium) and (Number of active pixels is low) and (number of objects is high) then (weight is less.)
xi) If (luminous sensitivity is dark) and (contrast sensitivity is high) and (edge sensitivity is medium) and (Number of on pixels is low) and ((number of regions is high) then (weight is Higher) (1)
xii) If (luminous sensitivity is dark) and (contrast sensitivity is medium) and (edge sensitivity is medium) and (Number of on pixels is low is low) and (number of regions is high) then (weight is Higher) (1)
xiii) If (luminous sensitivity is medium) and (contrast sensitivity is low) and (edge sensitivity is medium) and (Number of on pixels is low) and ((number of regions is high) then (weight is less) (1)
xiv) If (luminous sensitivity is medium) and (contrast sensitivity is medium) and (edge sensitivity is medium) and (Number of on pixels is high) and ((number of regions is low) then (weight is average) (1)
xv) If (luminous sensitivity is medium) and (con trast sensitivity is high) and (edge sensitivity is medium) and (Number of on pixels is high) (weight is and ((number of regions is low) then average) (1)
xvi) . If (luminous sensitivity is bright) and (con trast sensitivity is low) and (edge sensitivity is medium) and (Number of on pixels is high) and ((number of regions is low) then (weight is average) (1)
xvii) If (luminous sensitivity is bright) and (contrast sensitivity is medium) and (edge sensitivity is medium) and (Number of on pixels is high) and ((number regions is low) then (weight is average) (1)
xviii) If (luminous sensitivity is bright) and (con trast sensitivity is high) and (edge sensitivity is medium) and (Number of on pixels is low) and ((number of regions is high) then (weight is Higher) (1)
xix) If (luminous sensitivity is bright) and (con trast sensitivity is high) and (edge sensitivity is medium) and (Number of on pixels is low) and ((number of regions is high) then (weight is Higher) (1)
xx) . If (luminous sensitivity is dark) and (contrast sensitivity is low) and (edge sensitivity is large) and (Number of on pixels is high) and ((number of regions is low) then (weight is less)
xxi) If (luminous sensitivity is dark) and (contrast sensitivity is medium) and (edge sensitivity is large) and (Number of on pixels is low) and ((number of regions is high) then (weight is Higher) (1)
xxii) If (luminous sensitivity is dark) and (contrast sensitivity is high) and (edge sensitivity is large) and (Number of on pixels is low) and ((number of regions is high) then (weight is high) (1)
xxiii) If (luminous sensitivity is medium) and (con trast sensitivity is low) and (edge sensitivity is large) and (Number of on pixels is high) and ((number of regions is low) then (weight is average)

If (luminous sensitivity is medium) and (con trast sensitivity is medium) and (edge sensitiv ity is large) and (Number of on pixels is high) and ((number of regions is low) then (weight is average) (1)

xxv) If (luminous sensitivity is medium) and (contrast sensitivity is high) and (edge sensitivity is large) and (Number of on pixels is low) and ((number of regions is high) then (weight is Higher) (1)
xxvi) If (luminous sensitivity is bright) and (contrast sensitivity is low) and (edge sensitivity is large) and (Number of active pixels is high) and (number of objects is low) then (weight is Higher) (1)

xxvii) If (luminous sensitivity is bright) and (contrast sensitivity is low) and (edge sensitivity is large) and (Number of on pixels is high) and (number of regions is low) then (weight is Higher) (1)
xxviii) If (luminous sensitivity is bright) and (contrast sensitivity is high) and (edge sensitivity is large) and (Number of on pixels is low) and number of regions is high then weight is Highest) (1)

TABLE I
Details of fuzzy inference used in the paper

Type	'Mumdani'
And method	'Min'
Or method	'Max'
Defuzz method	'Centroid'
impMethod	'Min'
aggMethod	'Max'
Input	1 × 5
output	1 × 1
Rules	1 × 27

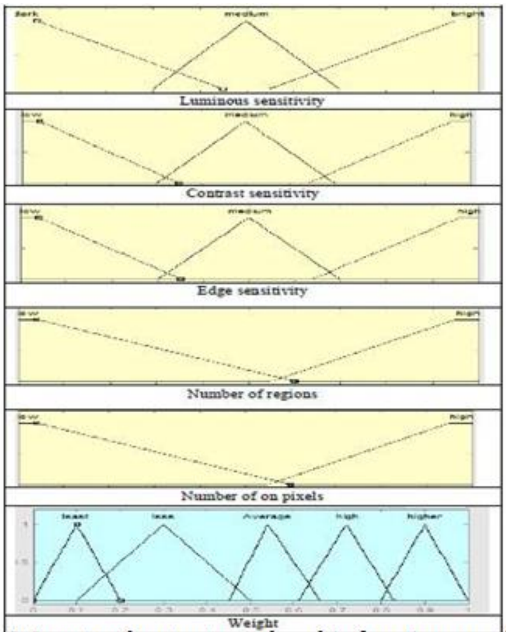


Fig. 2. Input and output membership functions used in algorithm.

f) Obtain weight α from fuzzy inference system for each 8 × 8 block using fuzzy inference logic.

g) Take watermark of size 32 × 32 and using rear-range bits to serially convert watermark into 1 dimensional vector.

h) Select, a robust location AC_p at the same po-sition from each 8 × 8 block.

i) Rearrange AC_q in the same position where watermark embedded.

j) Apply inverse DCT and obtain watermarked image.

$$AC_q = \begin{cases} AC_p + T & When\ W = 0 \\ AC_p - T & When\ W = 1 \end{cases} \quad (5)$$

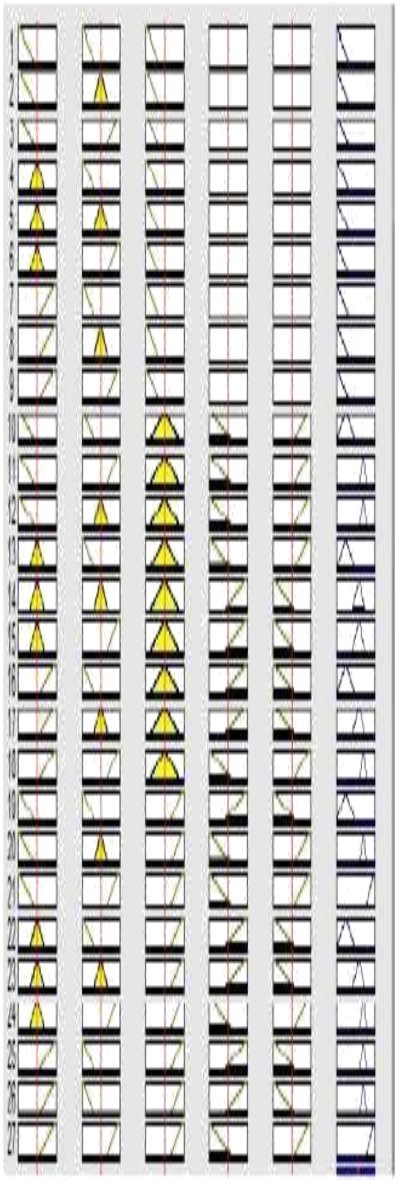


Fig. 3. Rule viewer of proposed scheme

3.2. Watermark Extraction

1) The input to watermark extraction is watermarked image and original watermark.
2) Apply DCT and segment it into 8 × 8blocks to the watermarked image and original image.
3) Apply FIS to both original and watermarked image.
4) Identify the embedding location AC_p and AC_q and before embedding the coefficient is and after embed-ding it becomes
5) if $AC_q > AC_p$ then watermark bit is 1 else watermark bit 0.
6) Concatenate all watermark bits.
7) Convert 2d Arrays into 1d array.
8) Extract watermark

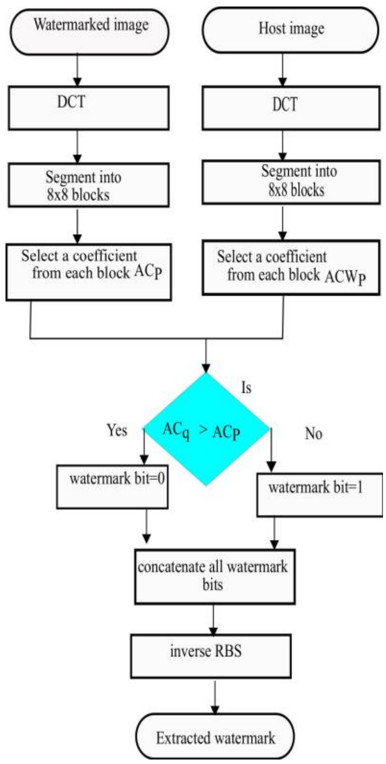


Fig. 4. Watermark Extraction Algorithm

4. Simulation results

The host images of size 512 × 512. gray scale cover images Lena, Mandril and Pirate are used. The watermark is 64 × 64 is a logo of Gokaraju Rangaraju institute of Engineering and Technology. The peak signal to noise ratio gives the measure of imperceptibility. Higher the P.S.N.R, the better imperceptibility.

4.1. Imperceptibility

Normally, in image processing, the quality of watermark is judged based on P.S.N.R. The P.S.N.R between water- marked and the original frame .

$$PSNR = 10 \log 10 \frac{255^2}{M.S.E} \quad (6)$$

As scaling factor is improved the imperceptibility is increased but the robustness against attacks reduced. A subjective evaluation test is conducted by 30 subjects and it unanimously confirmed that the perpetual invisibility of the watermark. The experimental set up was conducted on four images which consist of two copies of each image and the images are displayed on computer screen and the subjects were asked to carefully look at displayed image

TABLE II
Quantified values used in the algorithm for various parameters used in fuzzy inference

Parameter	Membership	Quantified value
Luminous sensitivity	Bright	1
	Medium	0.66
	Low	0.33
Contrast sensitivity	Bright	1
	Medium	0.66
	Low	0.33
Edge sensitivity	Bright	1
	Medium	0.66
	Low	0.33
Number of regions	less	0.5
	more	1
Number of on pixels	less	0.5
	more	1
Weight	least	0.33
	less	0.5
	Average	0.66
	High	0.88
	Highest	1

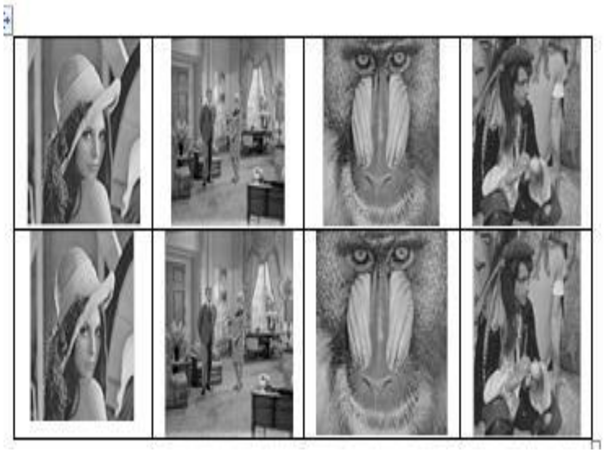


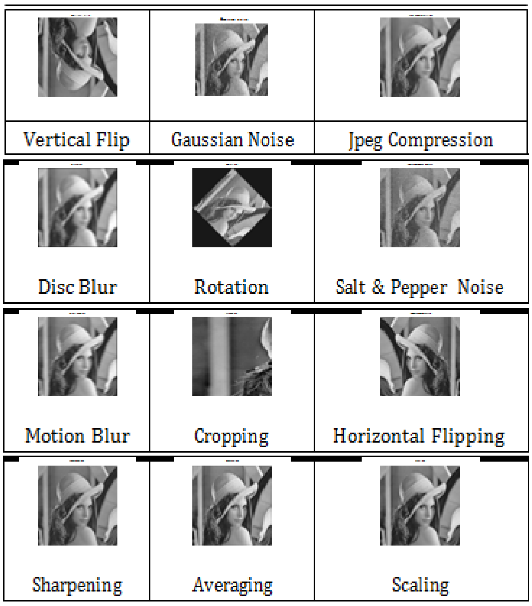
Fig. 5. Original images of lena, living room, Baboon, Pirate. And watermarked images of Lena, living room, Baboon and pirate.

TABLE III
Peak signal to noise ratio and N.C.C of different host images used in Algorithm

Image	Peak signal to Noise ratio	N.C.C
Lena	93.366	1
Mandril	66.3415	1
Pirate	89.999	1
Living room	66.333	1

and then report if there is any difference between the two images.

TABLE IV
Various watermarking attacks applied to Lena



4.2. Robustness

To assess the robustness of proposed watermarking algo-rithms several attacks are applied. These attacks include JPEG compression, rotation, cropping on both sides and salt &pepper and Gaussian noise. The bit error rate and normalized cross correlation is computed between original watermark and extracted watermark.

5. CONCLUSIONS

The images having more number of objects and less number of active pixels the imperceptibility is less. Con-trary to this for smoother images, the proposed method yield high imperceptibility. Fuzzy output is taken as nor-malized crisp output lying between 0 and 1. The pro-posed algorithm is found to be robust against number of attacks like JPEG compression (80%), Rotation, sym-metrical cropping up to The high peak signal to noise ratio and robustness against number of attacks signifies the proposed method is highly imperceptible and robust.

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