An Advanced Image Encryption Method Based on Fuzzy Transform in Two Variables and Edge Detection

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Abstract— We live in a world full of things connected to each other in various complex ways. A great deal of our time goes in interacting with one of the most important such things – Images. The need for securing the relay of images over the less secure networks increases as is the need for the simplest of the tasks such as viewing or editing an image. Image steganography is the procedure of hiding a secure message in a cover image thus creating a stego image which can secure the message throughout its course of travel from the sender to the receiver. In the present paper, we propose an advanced image encryption algorithm based on fuzzy transform [1] in two variables. The two variables being the values of the two dimensions of the image. The idea is to pre-process the image to reduce the file size but keeping the quality intact by using the F-transform and edge detection technology, then embedding it in the cover image, thus producing a much robust stego image with the least deviations in CSV values [2]

Keywords—*F-Transform, Steganography, Edge detection*

I. INTRODUCTION

As we are growing into the advanced world of artificial intelligence, virtual reality, and augmented vision technologies, getting it done is just not the primary concern anymore. With the increasing data hungry applications eating into our mammoth bandwidths, data security comes across as one of the most important aspect of computer science engineering, giving rise to the development of advanced algorithms and technologies to achieve it. And as we talk about the security techniques, we have travelled a long, learning distance since the very inception of the idea of data security. Steganography is one such technique. The reason for this technique being among the most popular of all data security technologies, is its ability to adapt and co-exist with other security processes being applied to the same input. That essentially gives away the secret why steganography is used with every other security technique available to the human being.

For the uninitiated, steganography is a phenomenon where a secret message is encoded into a cover image, thus producing a stego-image which looks just like the original cover image but has a secret message encoded within. This is the basic idea behind the technique but it has evolved gradually with time. The flexible properties of steganography enables the user to use more than one security technology to implement with it, still maintaining the independent properties of each of them. The most used security algorithms which are implemented with steganography are hashing, AES, RSA, etc. These security algorithms are used for additional security to make the message innocuous to the attacker, but are less concerned with the quality of the secret message. Here, the proposed algorithm in this paper very gradually tries to draw a clear line between security and quality.

The proposed algorithm at the sender side consists of four steps: data collection, fuzzy pre-processing of the image, encoding and transmission. The steps performed at the receiver side are: receiving the signal, decoding and reading the message. But prior to going into the particularsof the algorithm, first we shall discuss the processes involved.

II. F-TRANSFORM

The idea behind the universal concept of fuzzy transform was inspired by the subject of fuzzy modelling introduced by T. Takagi and M. Sugeno in 1985. The fuzzy transform, or the F-transform generally deals with the transformation of the original function into a skeleton model of functions. This leads to the development of powerful tools intended for solving several problems; image processing being the integral one. Initially, the F-transform was introduced for general functions with one or two variables. The ordinary F--transform is also denoted as the F^0-transform for functions with zero-order polynomials. But to extend this transform so as to cover the functions with higher degrees, it becomes important to generalize F^0-transform into the F^s-transform,$s \geq 1$.. Further, approximation of the partial derivatives of the function is done by using the components of F^s-transform.

III. EDGE-DETECTION BASED ON F^0-TRANSFORM

We shall start by portraying an edge with a membership function by assigning a belongingness degree to each pixel of the image with the help of a fuzzy set.

Let us assume that u is an input image with the domain $P = [1, N] \times [1, M]$ and the number of fuzzy sets are n and m in a fuzzy partition. Constraints n, m limit the robustness of the corresponding partition, and they are significant parameters in our methodology. They recountthe size of thelocality of chosen pixels and consequentlypower the thickness of the individual edges according to the rule: the greater the values of n and m, the "thinner" the matching edges. The whole idea of the Edge Detection algorithm is based off of this notion.

The following formal expression represents the membership function of edge E:

$$E = \{(p_i, q_j) \in P \,|(\exists k, l)(p_i \in A_k) \; and \; (q_j \in B_l) \; and \; |\, u(p_i, q_j) - F^0_{kl} \,|\}$$

Here,∃ denotes addition; 'and' denotes the product; ($p_i \in A_k$) is represented as $A_k(p_i)$ (likewise, $q_j \in B_l$); and hence$|\, u(p_i, q_j) - F^0_{kl} \,|$ is bumped to the value of [0, 1]. Thus, the membership degree $E(p_i, q_j)$is given by

$$\left|\sum_{k=1}^{n}\sum_{l=1}^{m} A_k(p_i)B_l(q_j)\big(u(p_i, q_j) - F^0_{kl}\big)\right|$$

Thus, the following representation can be obtained, which will then be used in the edge detection algorithm. For all $(p_i, q_j) \in P$

$$\begin{aligned} E(p_i, q_j) \in P &= \left|u(p_i, q_j) - u^0(p_i, q_j)\right| \\ &= \left|\sum_{k=1}^{n}\sum_{l=1}^{m} A_k(p_i)B_l(q_j)\big(u(p_i, q_j) - F^0_{kl}\big)\right| \\ &\le \sum_{k=1}^{n}\sum_{l=1}^{m} A_k(p_i)B_l(q_j)\left|\big(u(p_i, q_j) - F^0_{kl}\big)\right| \end{aligned}$$

Let us now define the focalstages of the edge detection algorithm, which is established upon the above suggesteddescription and practices the F^0-transform of the image function u:

1. Calculate $F^0_{nm}[u] = (F^0_{kl}), k = 1, \ldots, n, l = 1, \ldots, m$ – the direct F^0-transform of u;
2. Calculate $u^0(p_i, q_j)$; $(p_i, q_j) \in P$ – the inverse F^0-transform of u;
3. Calculate for all $(p_i, q_j) \in P$ the residuum function

$$E(p_i, q_j) \in P = \left|u(p_i, q_j) - u^0(p_i, q_j)\right|$$

4. Rescale and round off the values of E from $[0, max_{(p_i, q_j) \in P} E(p_i, q_j)]$ to the numerals in [0,255], which shall results in the new image E_r

We implemented these stages in our experiments and found some astonishing results. The same have been discussed in the following section.

IV. Experiments and Results

A. Edge Detection based on F^0-Transform

As declared in the preceding section, the input parameters n and m (the numbers of fuzzy sets) of the Edge Detection algorithmregulate the "width" of the edges. According to the above expressed rule, the greater the values of n and m, consistently, the lesser number of pixels covered by every basic function

$$(A_k \times B_l), k = 1, \ldots, n, l = 1, \ldots, m)$$

and hence, the "thinner" the resultant edges. The graphics of the image edge functions E_r, with variable settings of parameters n and m are given in Fig.2 - 5, along with the original image in Fig.1. Unsurprisingly, blurred images with a different depth of focus or objects in shadow ischallenging. Let us demonstrate here the second case and show how the setting of the edge width (i.e., the variable setting of n and m) affects the resultant images.

Fig. 1Edge detection by the F^0-transform - Original image.

Fig. 2 Edge detection by the F^0-transform - Image edge function E_r (4 pixels covered by one basic function).

Fig. 3 Edge detection by the F^0-transform - Image edge function E_r (10 pixels covered by one basic function).

Fig. 4 Edge detection by the F^0-transform - Image edge function E_r (20 pixels covered by one basic function).

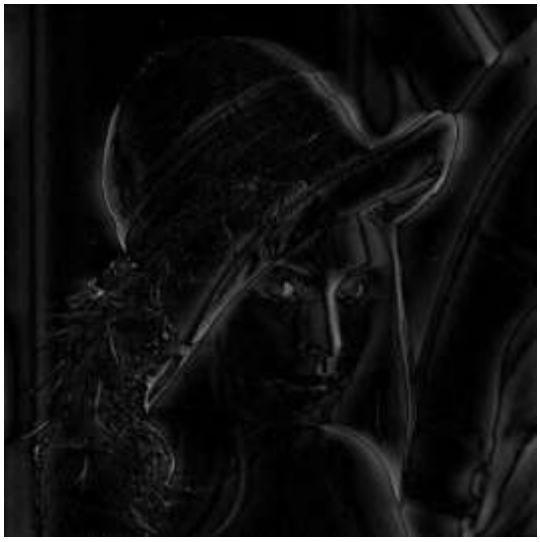

Fig. 5 Edge detection by the F^0-transform - Image edge function E_r (50 pixels covered by one basic function).

B. F-Transform graphs in 3D

Following are the cosine shaped 3D depictions of an original function $f(x, y) = \sin(x) * \sin(y)$, its F-Transform and the difference.

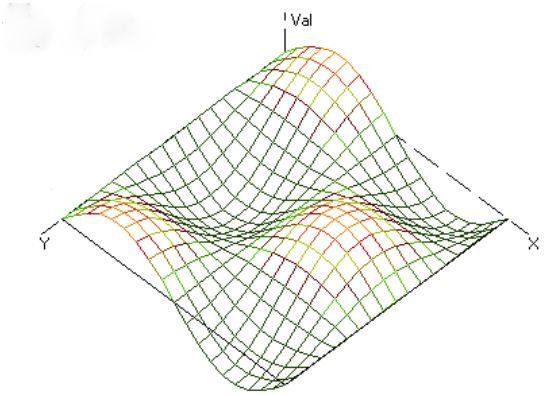

Fig. 6 Cosine shaped Original function.

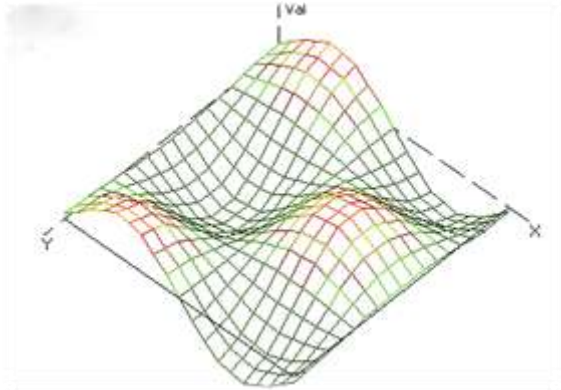

Fig. 7 Approximated graph of the F-Transform of the original function.

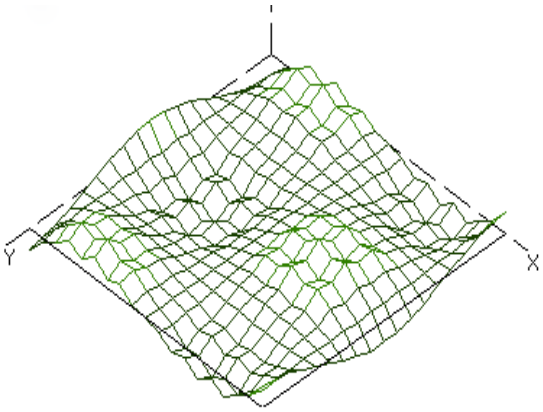

Fig. 8 Difference graph.

V. THE ALGORITHM

The proposed algorithm involves use of the fuzzy image compression technique based on fuzzy edge detection and F-transform to pre-process the image and the following process of encoding. This way, we can ensure that the transmitted image possesses the unmatched extent of quality and security. The flowchart for the process can be demonstrated as follows:

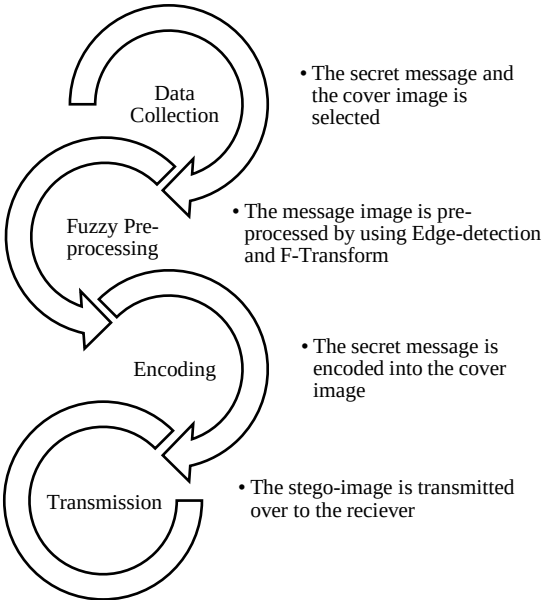

Fig. 9 Process chart for the sender side.

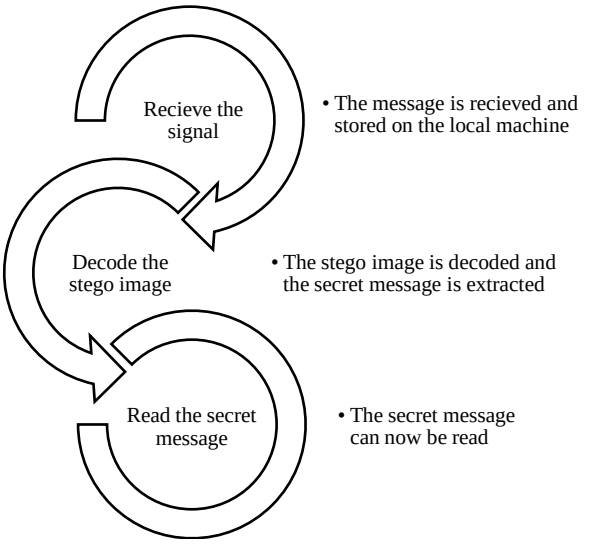

Fig. 10 Process at the receiver side.

VI. CONCLUSION

There are numerous ways to exploit the advantages the fuzzy technology provides us. The method discussed in this paper enlist one such advantage of the fuzzy technology and edge detection technique to encode secret messages and ensure the security through transmission. The technology itself is new and gives endless opportunities to extend and apply the advantages to numerous everyday electronic activities.

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