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# AN APPROACH FOR IMAGE QUALITY ASSESSMENT USING INTUITIONISTIC FUZZY SETS

**A. Elaraby[1,a] , A. Nechaevskiy[2]**

[1] *Department of Computer Science, South Valley University, Egypt.*

[2] *LIT, Joint Institute for Nuclear Research, Dubna, Russia.*

E-mail: [a]a.elaraby87@gmail.com

Image quality impact the ability of practitioners while they are using image information. In this work, we utilize Intuitionistic Fuzzy Sets (IFSs) theory for image quality assessment. In recent years, Intuitionistic Fuzzy Sets has increased much significance in various fields of signal and image processing as it considers the uncertainty in the assignment of membership called the hesitation degree. A reliable Image Quality Assessment is proposed based on generalized exponential intuitionistic fuzzy entropy.

Keywords: Image Quality; Intuitionistic Fuzzy Sets; Exponential Entropy

# 1. Introduction

Image quality assessment has been a topic of intense research over the last several decades. With each year come an increasing number of new quality assessment algorithms, extensions of existing quality assessment algorithms, and applications of quality assessment to other disciplines [1-5]. Many applications in several topics of signal and image processing have been presented based on the theory of fuzzy set presented by Zadeh [6-12]. Similarity and distance measuring between IFSs is now being extensively used in various applications like pattern recognition [13], decision making and fuzzy clustering [14-15]. Handle imprecision and uncertainty is considered by using the theory of fuzzy set (FS) which characterized by a membership function between zero and one. Taking into consideration the hesitation or uncertainty about the membership degree, in real life situations the degree of non-membership is not always handle as in FS theory. To solve this task, Atanassov [16-18] proposed as an extension of FS called Intuitionistic Fuzzy Sets (IFSs). Since the appearance of intuitionistic fuzzy sets (IFSs), much research has been presented that measures the similarity and distance between IFSs. In [19] authors utilizing geometric interpretation to proposed four distance measures between IFSs. In [20] comprehensive overview of IFS distance and similarity measures is presented. In [21] author proposed IFSs distance metric that makes use of fuzzy implications and matrix norms. In [22] author used the convex combination of endpoints to present a new IFSs similarity measure and focusing on the property of min and max operators. In this paper, we present a reliable Image Quality Assessment based on the concept of generalized exponential intuitionistic fuzzy entropy. The novel measure considers membership degree, non-membership degree and hesitation degree.

Recently, high-performance computing systems is necessary techniques for analysis of the large set of images. To use all the capabilities of such systems, it is necessary to develop parallel algorithms for already existing single threaded versions of algorithms implementations. The transition to advanced digital technology, such as high-performance hybrid computing technologies (parallel computing technologies on a cluster, on a graphic cards, etc.), for solution of a similar class of problems, allows in a short time to obtain physically significant world-class results. Thus, the research work presented in this paper can be extended to parallelization considering its features. A good computing platform available through JINR can be used for extension of this work, as JINR actively participates in different international projects which are relied on advanced computing technologies. A unique computer infrastructure has been created at LIT JINR, which makes it possible to use a supercomputer, a hybrid cluster, and cloud computing for research. The Heterogeneous platform "HybriLIT" is the part of the JINR Multifunctional Information and Computing Complex [MICC] for high-performance computing. The HybriLIT platform consists of two elements, i.e. the education and testing polygon and the "Govorun" supercomputer, combined by a unified software and information environment [NEC2019]. The "Govorun" supercomputer commissioned in 2018, is aimed to cardinally accelerate complex theoretical and experimental studies in all projects underway at JINR. "HybriLIT" heterogeneous cluster is intended for performing computations with the use of parallel programming technologies. Heterogeneous structure of computational nodes allows developing parallel applications for the solution of a wide range of mathematical resource intensive tasks using the whole capacity of multicore component and computation accelerators [23].

The paper is organized as follows. In Section 2, describes the proposed measure. Section 3 describes the application of proposed measure in Image Quality Assessment and experimental results. The conclusion is presented in Section 4.

# 2. Proposed Intuitionistic Fuzzy Divergence

In [24] authors proposed a new information measure for Atanassov's intuitionistic fuzzy sets, calling it exponential intuitionistic fuzzy entropy. This measure based on the concept of exponential fuzzy entropy is defined in [25]. This approach is found particularly useful in situations where data is available in terms of intuitionistic fuzzy set values, but implementation requirements are only fuzzy. In the practice, the hesitation part is ignored. But it is possible to obtain a better result by not ignoring the hesitation; in fact, a better result is obtained if we merge the hesitation part suitably. The result is an approach that may help applications of IFS data in industry, where the tools used are those of fuzzy set theory.

In this section, a novel measure is proposed based on the concept of generalized exponential intuitionistic fuzzy entropy, we called as New Intuitionistic Fuzzy Divergence (*NIFD*).

Let $\alpha = \{(x, \mu_\alpha (x), \upsilon_\alpha (x) \mid x \in X)\}$ and $\beta = \{(x, \mu_\beta(x), \upsilon_\beta(x) \mid x \in X)\}$ be two intuitionistic fuzzy sets. Considering the hesitation degree, the interval or range of the membership degree of the two intuitionistic fuzzy sets $\alpha$ and $\beta$ may be given as $\{(\mu_\alpha(x), (\mu_\alpha(x) + \pi_\alpha(x))\}, \{(\mu_\beta(x), (\mu_\beta(x) + \pi_\beta(x))\}$ where $\mu_\alpha(x)$, $\mu_\beta(x)$ are the membership degrees and $\pi_\alpha(x), \pi_\beta(x)$ are the hesitation degrees in the respective sets, with $\pi_\alpha(x) = 1 - \mu_\alpha(x) - \upsilon_\alpha(x)$ and $\pi_B(x) = 1 - \mu_\beta(x) - \upsilon_\beta(x)$. The interval is due to the hesitation or the lack of knowledge in assign membership values. The distance measure has been proposed here considering the hesitation degrees. In an image of size $M \times M$ with $L$ distinct gray levels having probabilities $p_0, p_1, \dots \dots, p_{L-1}\}$, the exponential entropy is defined as: $H = \sum_{i=0}^{L-1} p_i e^{1-p_i}$.

In fuzzy cases, an image $A$ of size $M \times M$ fuzzy entropy s [11] is:

$$H(A) = \frac{1}{n(\sqrt{e}-1)} \sum_{i=0}^{M-1} \sum_{j=0}^{M-1} [(\mu_A(a_{ij}) e^{1-\mu_A(a_{ij})}) + (1 - (\mu_A(a_{ij}) e^{\mu_A(a_{ij})})) - 1] \quad (1)$$

where $n = M^2, i, j = 0,1,2, \dots \dots .., M-1,$ and $\mu_A(a_{ij})$ membership degree of $(i,j)$th pixels $a_{ij}$ of an image $A$.

For images $A$ and $B$, the amount of information between the membership degrees of images $A$ and $B$ is given in [11]:

(i) due to $m_1(A)$ and $m_1(B)$ i.e., $\mu_A(a_{ij})$ and $\mu_B(b_{ij})$ of the $(i,j)$th pixels:
$e^{\mu_A(a_{ij})} / e^{\mu_B(b_{ij})}$ or $e^{\mu_A(a_{ij}) - \mu_B(b_{ij})}$.

(ii) due to $m_2(A)$ and $m_2(B)$ i.e., $\mu_A(a_{ij}) + \pi_A(a_{ij})$ and $\mu_B(b_{ij}) + \pi_B(b_{ij})$ of the $(i,j)$th pixels: $e^{\mu_A(a_{ij}) + \pi_A(a_{ij})} / e^{\mu_B(b_{ij}) + \pi_B(b_{ij})}$.

The Generalized Exponential Fuzzy Entropy [24]:

$$eH(A) = \frac{1}{n(\sqrt{e}-1)} \sum_{i=0}^{M-1} \sum_{j=0}^{M-1} [(z_A(a_{ij}) e^{1-z_A(a_{ij})}) + (1 - (z_A(a_{ij}) e^{z_A(a_{ij})})) - 1] \quad (2)$$

$$z_A(a_{ij}) = \frac{\mu_A(a_{ij}) + 1 - \upsilon_A(a_{ij})}{2} \quad (3)$$

The divergence between images $A$ and $B$ by corresponding Generalized Exponential Fuzzy Entropy, is:

$$D_1(A,B) = \sum_i \sum_j \left(1 - (1 - z_A(a_{ij})) e^{z_A(a_{ij}) - z_B(b_{ij})} - z_A(a_{ij}) e^{z_B(b_{ij}) - z_A(a_{ij})}\right) \quad (4)$$

Similarly, the divergence of $B$ against $A$ is:

$$D_1(B,A) = \sum_i \sum_j \left(1 - (1 - z_B(b_{ij})) e^{z_B(b_{ij}) - z_A(a_{ij})} - z_B(b_{ij}) e^{z_A(a_{ij}) - z_B(b_{ij})}\right) \quad (5)$$

So, the total divergence as:

$$Div - m_1(A,B) = D_1(A,B) + D_1(B,A)$$
$$= \sum_i \sum_j \Big(2 - (1 - z_A(a_{ij}) + z_B(b_{ij})) e^{z_A(a_{ij}) - z_B(b_{ij})} - (1 - z_B(b_{ij}) + z_A(a_{ij})) e^{z_B(b_{ij}) - z_A(a_{ij})}\Big) \quad (6)$$

$$Div - m_2(A,B) = D_1(A,B) + D_1(B,A)$$
$$Div - m_2(A,B) = \sum_i \sum_j \Big(2 - [1 - z_A(a_{ij}) - z_B(b_{ij}) + \pi_B(b_{ij}) - \pi_A(a_{ij})] e^{(z_A(a_{ij}) - z_B(b_{ij})) - (\pi_B(b_{ij}) - \pi_A(a_{ij}))} - [1 - (\pi_B(b_{ij}) - \pi_A(a_{ij})) + z_A(a_{ij}) - z_B(b_{ij})] e^{(\pi_B(b_{ij}) - \pi_A(a_{ij})) - (z_A(a_{ij}) - z_B(b_{ij}))}\Big) \quad (7)$$

Thus, the overall of *NIFD* between the images $A$ and $B$ by adding Eqs. (6) and (7) as:

$NIFD(A,B) = Div - m_1(A,B) + Div - m_2(A,B)$

$$NIFD(A,B) = \sum_i \sum_j \Big(2 - (1 - z_A(a_{ij}) + z_B(b_{ij}))e^{z_A(a_{ij}) - z_B(b_{ij})} - (1 - z_B(b_{ij})) + z_A(a_{ij})e^{z_B(b_{ij}) - z_A(a_{ij})}] + \sum_i \sum_j ( 2 - [1 - z_A(a_{ij}) - z_B(b_{ij}) + \pi_B(b_{ij}) - \pi_A(a_{ij})]e^{(z_A(a_{ij}) - z_B(b_{ij})) - (\pi_B(b_{ij}) - \pi_A(a_{ij}))} - [1 - (\pi_B(b_{ij}) - \pi_A(a_{ij})) + z_A(a_{ij}) - z_B(b_{ij})]e^{(\pi_B(b_{ij}) - \pi_A(a_{ij})) - (z_A(a_{ij}) - z_B(b_{ij}))})\Big) \quad (8)$$

# 3. Application to Image Quality Assessment

The $NIFD$ at each pixel position $(i,j)$ of an image $NIFD(i,j)$, is calculated between the reference image and the other image (same size as that of the reference image) as:

$$NIFD(i,j) = NIFD(A,B) \quad (9)$$

The $NIFD$ between $A$ and$B$,$NIFD(A,B)$, is calculated by finding the $NIFD$ between each of the elements $a_{ij}$and $b_{ij}$ of the reference image $A$ and image $B$ using Eq. (8). Finally, $NIFD$ matrix, the same size as that of image, is formed with values of $NIFD(i,j)$ at each point of the matrix. This $NIFD$ matrix is indexed to get an image quality measure. To explore the performance of the new algorithm, the image is distorted by a wide variety of corruptions: Salt & pepper noise, Gaussian noise, Poisson noise, speckle noise, blurring, stretching and Compression. All the analyses were performed using MATLAB. To investigate the new algorithm effectiveness, we have compared it to SSIM that considered well known measure.

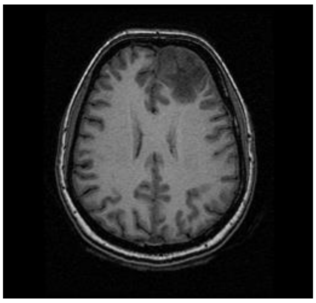
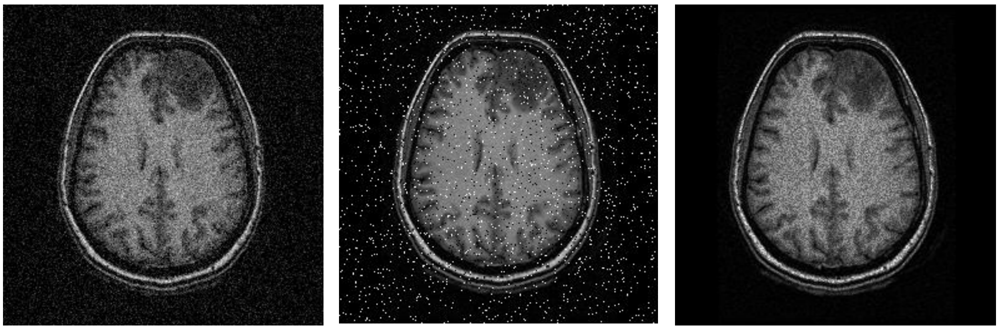
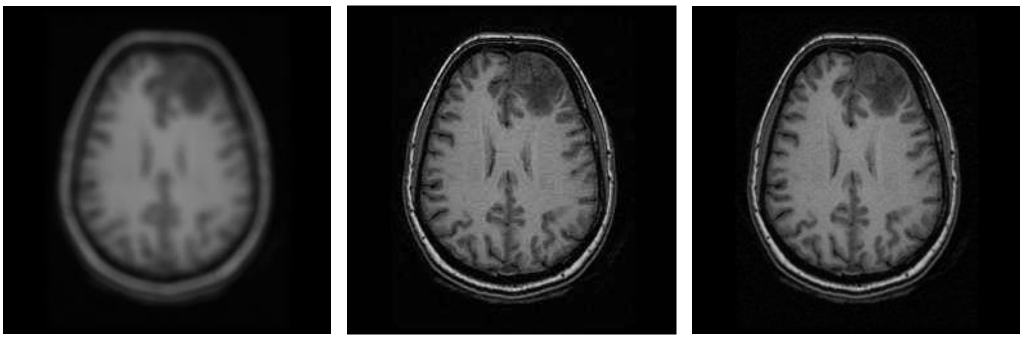


Fig.1. Original CT brain image



(a) Gaussian noise (b) salt & pepper noise (c) speckle noise



(d) Blurring (e) Compression (f) stretching

Fig.2. The CT brain test image is distorted by a wide variety of corruptions: (a) additive Gaussian noise, (b) impulsive salt-pepper noise, (c) multiplicative speckle noise, (d) blurring, (e) JPEG compression and (f) contrast stretching.

Table 1. Evaluation of CT Brain Image with Different Types of Distortions

| **Image** | **Distortion Type** | **Proposed IQM** | **SSIM** |
|---|---|---|---|
| Fig. 2 (a) | Additive gaussian noise | **0.1609** | **0.2114** |
| Fig. 2 (b) | Impulsive salt-pepper noise | **0.8071** | **0.2576** |
| Fig. 2 (c) | Multiplicative speckle noise | **0.4329** | **0.8025** |
| Fig. 2 (d) | Blurring | **0.2400** | **0.3747** |
| Fig. 2 (e) | JPEG compression | **0.0864** | **0.4451** |
| Fig. 2 (f) | Contrast stretching | **0.2729** | **0.9566** |

## 4. Conclusion

In this paper, the novel application of Intuitionistic Fuzzy Set in image quality assessment is introduced. A new measure is proposed that utilize the Generalized Exponential Intuitionistic Fuzzy Entropy. This measure has been applied on images for the purpose of quality assessment. Experimental results for a wide variety of corruptions for image are presented. The proposed approach clearly measures the quality of images. In our view, the results are reliable due to uses the Intuitionistic Fuzzy Set to assign the membership degrees, in consideration of the uncertainty. Future research in taking the uncertainty into account will lead to even better performance.

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