Applied Soft Computing 30 (2015) 441–453

Contents lists available at ScienceDirect

Applied Soft Computing

journal homepage: www.elsevier.com/locate/asoc

No-reference image quality assessment using interval type 2 fuzzy sets

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ARTICLE INFO

Article history:
Received 2 March 2014
Received in revised form 19 January 2015
Accepted 28 January 2015
Available online 7 February 2015

Keywords:
Visually salient regions
Mean opinion score
No-reference image quality
Interval type 2 fuzzy sets

ABSTRACT

Image quality assessment of distorted or decompressed images without any reference to the original image is challenging from computational point of view. Quality of an image is best judged by human observers without any reference image, and evaluated using subjective measures. The paper aims at designing a generic no-reference image quality assessment (NR-IQA) method by incorporating human visual perception in assigning quality class labels to the images. Using fuzzy logic approach, we consider information theoretic entropies of visually salient regions of images as features and assess quality of the images using linguistic values. The features are transformed into fuzzy feature space by designing an algorithm based on interval type-2 (IT2) fuzzy sets. The algorithm measures uncertainty present in the input–output feature space to predict image quality accurately as close to human observations. We have taken a set of training images belonging to five different pre-assigned quality class labels for calculating foot print of uncertainty (FOU) corresponding to each class. To assess the quality class label of the test images, maximum of T-conorm applied on the lower and upper membership functions of the test images belonging to different classes is calculated. Our proposed image quality metric is compared with other no-reference quality metrics demonstrating more accurate results and compatible with subjective mean opinion score metric.

1. Introduction

Digital images are subjected to loss of information, various kinds of distortions at the time of compression [12] and transmission, which deteriorate visual quality of the images at the receiving end. Quality of an image plays fundamental role to take vital decision and therefore, its assessment is essential prior to application. Despite rapid advancement in technology, the characteristics of human vision are still considered best performer for quality assessment processes. Modeling physiological and psycho visual features of the human visual system (HVS) [16–18] are reported for developing image quality assessment (IQA) methods [23]. Due to limited knowledge of HVS, computational HVS modeling used in IQA is far from complete. The most reliable means of assessing image quality is subjective evaluation based on the opinion of the human observers [9,13]. However, subjective testing is not automatic, lengthy process and expensive too.

Most objective image quality assessment methods [12,14,64–68] either require access to the original image as reference [8,14,67,68] or only can evaluate images, degraded with predefined distortions [64–66,76] and therefore, lacking generalization approach. Reduced reference IQA methods [13,64–66] provide a solution by extracting a minimal set of parameters from the reference image for cases where the reference image is not fully accessible. However, determination of the effective parameter set is an important issue. No-reference IQA algorithms [60–77] attempt to perform quality evaluation for specific type of distorted images [60–62] and designed specifically for JPEG or JPEG2000 compression artifacts [15]. Two prominent works by Wang et al. [10] and Sheikh [9] have been reported relating to no-reference image quality assessment. JPEG image quality index and quality metric based on natural scene statistics (NSS) model are the respective metrics proposed [9] for evaluation of image quality. Extreme learning machine classifier based mean opinion score (MOS) estimator [26], discrete cosine transform (DCT) domain statistics based metric [27] and blind image quality index [24,25] are the three no-reference methods are reported very recently to assess image quality. But none of them incorporated human centric computation methods that can exploit powerful judgment

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http://dx.doi.org/10.1016/j.asoc.2015.01.064
1568-4946/

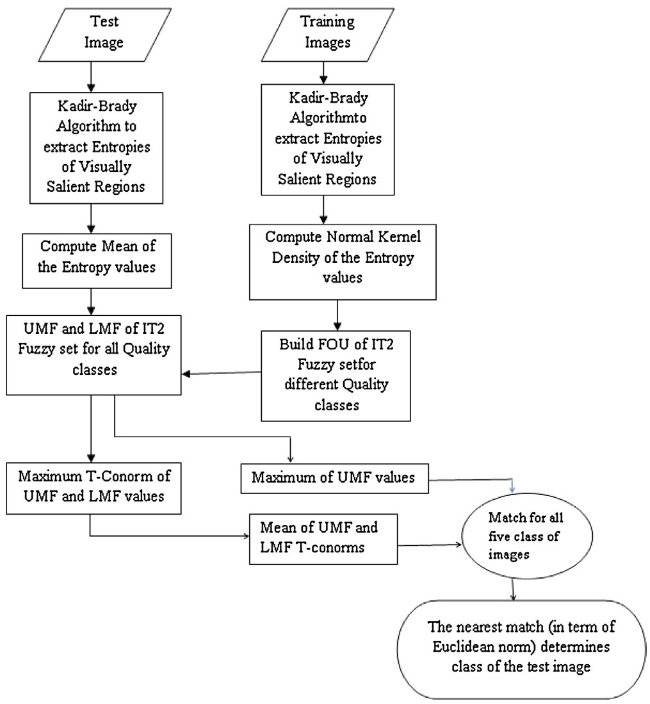

Fig. 1. Flow diagram of the proposed NR-IQA method.

ability of human observers like subjective methods, best suited for assessing quality of images.

In computer vision global and/or local features are extracted for image analysis and importance of the features depends on the area of application [37]. In subjective image quality evaluation methods, local features are more relevant [57,59,63] since human perceive the image based on salient points rather considering the image as a whole for predicting its quality. Salient features of images create varied degree of impression on human observers in assessing quality of the images without any reference image. Therefore, designing of a no reference image quality assessment method depends on human interpretation about the interrelation between the input features and output quality of the images and modeled as fuzzy rules using linguistic variables.

Fuzzy modeling is used to transform knowledge of human experts into mathematical models [1–6]. It can be used as a tool to assist human perception about a given task by transforming human observations into mathematical understanding [30–33,77]. The proposed no-reference image quality assessment (NR-IQA) method using fuzzy techniques is described using Fig. 1, where subjective evaluation strategy of human beings are modeled with the help of salient features of the images. Type-1 fuzzy logic based inference system and fuzzy relational classifier [36] have already been built [40] considering human perceptual vagueness [38] in assessing quality of images using linguistic values. However, subjective judgment by human observers about quality of image is associated with uncertainty in input (feature) and output (quality class label) space for which an exact membership function is difficult to design.

In type-1 fuzzy systems, the degree of membership of an image belonging to a particular class representing quality of an image is crisp. However, human perception has wide variation both on image features and image quality, therefore it is difficult to interpret and measure the linguistic variables by type-1 fuzzy set [58]. So to evaluate uncertainty associated with human perception in assessing image quality, type-2 fuzzy based systems has been proposed in the paper to depict the scenario. The membership functions of input–output variables of type-2 fuzzy systems are considered as type-1 fuzzy sets instead of crisp value.

In the paper, we have handled uncertainty in human visual perceptual inference generating process by determining image quality using interval type-2 fuzzy sets. Interval type-2 fuzzy set is used within a bounded range for representing degree of membership values, called foot print of uncertainty. Input features are measured by evaluating the entropy of visually salient regions as proposed by Kadir–Brady algorithm [34,39]. In interval type-2 fuzzy set, membership grade of each feature has been represented as an interval of lower and upper bound instead of a crisp value to transform it into fuzzy feature space. We have taken a set of training images belong to five different classes and foot print of uncertainty (FOU) of each class is calculated by designing a fuzzy based NR-IQA method. Quality of a new image is assessed using fuzzy operator applied on the lower and upper membership functions of the test images obtained from the FOUs of the training images.

The paper has been organized as: Section 2 describes feature selection procedure using Kadir–Brady algorithm, Section 3 presents transformation of features into type-2 fuzzy feature space, Section 4 proposes a NR-IQA method using interval type-2 fuzzy set, Section 5 shows results when applied to test images and finally conclusions are summarized in Section 6.

2. Feature selection

Entropy values of visually salient regions are considered as features to evaluate subjective quality of the images into different classes by the proposed NR-IQA method. Kadir and Brady algorithm [34,39] invariant to affine transformation has been invoked in the paper to extract visually salient regions and Shannon's entropy [4] values of the salient regions are calculated to measure uncertainty in the local feature space. The entropies are ranked according to their saliency.

2.1. Visually salient regions

Performance of subjective image quality assessment method depends on how quickly regions of interest in the image are identified by the method. Regions of interest are known as visually salient regions and it has been observed that in high quality images a large number of such regions exist. In the literature [43–46] different methods are reported to find visually salient regions out of an image. The earliest methods [48–56] of extracting edges from an image to build object contour is based upon the assumption that edges are more salient than other parts of an image. Gilles [21] reported that visually salient regions are rare in natural images and depends on the descriptor type used to define the regions. Highly differentiable descriptors treat every pixel rare whereas using non-differentiating descriptors more salient regions are identified. Schiele [20] demonstrated that visually salient regions posses a property which maximizes discrimination between the objects in an image. Fig. 2 [47] shows salient regions marked by red color, which are rare in the image.

Generally, visual saliency refers to the concept that certain parts of the scene are pre-attentively distinctive and create some form of significant visual arousal within the early stages of the Human Visual System [21]. Information theoretic entropies of visually salient regions are called regional entropy values, used in the paper as local features to develop no-reference image quality assessment (NR-IQA) method. Uncertainty in pixel intensity of local features is evaluated using Shannon's entropy [22] that determines stability of the system. Uniform image with peaked histogram indicate low complexity or high predictability while neighborhoods with flat intensity distributions demonstrate higher complexity of the