Perceptual quality assessment of geometrically distorted images

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Digital images are subject to various kinds of distortions that may result in a degradation of visual quality during acquisition, processing, compression, storage, transmission and reproduction. It is therefore necessary for many applications to be able to quantify the image quality degradation that occurs in a system, so that it is possible to control and enhance the quality of the images it produces. In this context the goal of objective image quality assessment is to design a quality measure based on the human vision model that can predict the perceived image quality automatically. The objective measure should give a numerical value quantifying the dissatisfaction of a typical human viewer when observing the reproduced image in place of the original.

Despite the existence of several studies on human perception of image quality, only few works \cite{1} can be found in the scientific literature dealing with the quality assessment of geometrically distorted images and the limitation of the metrics proposed so far is that they just rely on the displacement field defining the distortion without taking into account the characteristics of the images. This is a relevant problem since the same distortion applied to two different images can result in a different perceived image quality.

After a description of the problem of the assessment of geometric distortions in images and a review of the solutions proposed so far in the literature, we introduce an objective quality metric for geometrically distorted images, which has a good correspondence to the human perception of the distortions.

The basic idea of our approach is the following. It is well known that the main function of the HVS when looking at an image is to extract structural information from the viewing field \cite{2}, therefore a measurement of structural distortions should be a good approximation of perceived image distortion, since the more distortion affects the structure of the objects in the visual scene, the more the corresponding degradation is visible and annoying. Human vision is sensitive to bars and edges, for this reason structures of objects in images are typically outlined by edges and bars. Hence, we expect that a measure that links the displacement field describing the distortion with the presence of edges and bars in the image is likely to provide an adequate measure. We decided to use Gabor filters to extract bar and edges information from the images and to use these features to evaluate the perceptibility of the distortions.

Two sets of subjective experiments were carried out with different purpose following the ITU-T Recommendation P.910.13. The first set of experiments was performed to tune the objective metric with psychovisual data in order to transform them into a perceptual metric.
and to set the parameters of metric. The second set of experiment was conducted to validate the proposed metric. The experimental results show good performances of the proposed metric that outperforms the quality metrics proposed so far.

A so defined metric can play different roles, in fact the problem of geometric distortions and geometric correction is widely explored in different fields of image processing. In the context of medical imaging, for example, a great attention has been paid to study and correct the distortions that affect magnetic resonance imaging in the radiotherapy [3]. In the same way, geometric distortions introduced by the Landsat imaging system are well-known: the satellite does not provide information with sufficient accuracy to determine the geographical position of each pixel thus, to map the data onto the desired space, it is necessary to model a geometric transformation from a set of ground control points.

Lately, local geometric distortions have been mainly studied in the field of digital watermarking. The use of digital watermarking in real applications, in fact, is impeded by the weakness of current available algorithms against signal processing manipulations leading to the de-synchronization of the watermark embedder and detector. For this reason the problem of watermarking under geometric attacks has received considerable attention. Specifically it could be very useful to know the amount of geometric distortions that can be applied before the distorted image loses its commercial value or its meaning in order to develop an ad-hoc decoding algorithm and eventually obtain watermark synchronization through exhaustive search.

The lack of objective visual quality measures for geometric distortions has other consequences in the data hiding research. Without an objective quality measurement system, it is very difficult to compare the robustness of various watermarking or steganographic systems that embed information by changing the geometric features of the image. Such a metric could be also integrated in benchmark tools and allows to define a common standard with which to measure the performance of the watermarking systems. Other applications could be the use of this metric in a steganalysis tool as a feature in detecting hidden messages or in anti-collusion fingerprinting schemes based on random pre-warping.

References