# Quality Assessment of Degraded Natural Images due to Changes in Weather Conditions

Abstract of the Thesis
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# Abstract of the Ph. D. thesis submitted by RATNADEEP DEY

Image Quality Assessment is the field of research where the quality of an image has been estimated. This is an essential part of image processing research. Image is the primary resource of the research field, and the processing of images is the main aim of this research. Accessing the quality of the input image is mandatory for obtaining the best possible processing outcome. This thesis concentrates on the research field, namely image quality assessment. It contributes novel image quality assessment matrices and some image quality assessment-based application systems to solve problems from different domains like healthcare, industrial automation, surveillance systems, and weather classification. This dissertation focuses on the research domain of Image Quality Assessment.

This thesis mainly addressed the research domain named image quality assessment. The main goal of the dissertation is to provide algorithms to assess the quality of degraded natural images due to weather degradation. This dissertation achieves this goal by proposing novel algorithms to evaluate the quality of images degraded by natural stimuli. However, the dissertation discusses the other aspects of image quality assessment research and research on different image processing segments, like medical image processing, image de-raining, and object identification. The complete scope of the dissertation has been discussed in this section. The dissertation has a broad scope and various orientations. The main focus of this dissertation is the image quality assessment of degraded natural images due to weather degradation. Other sub-areas of image quality assessment and different sub-domains of image processing have been addressed in relation to the key topic. Discussing different orientations may help express the overall scope of the dissertation. Orientations of the dissertations to be addressed include contribution to research, application orientation, technological orientation, and experimental data.

The scope of the dissertation in the orientation of research contribution has to be addressed. Mainly, the research areas where the dissertation contains novel contributions have been enlisted below –

● The main research area addressed here is coined as Objective Image Quality Assessment, commonly known as Image Quality Assessment. In section 1.3.2, it has been stated that three techniques are available in the literature to assess the quality of an image. They are – Full reference image quality assessment, Reduced reference image quality assessment, and no reference image quality assessment. This dissertation's research contribution is limited to full-reference and no-reference image quality assessment. Reduced reference image quality assessment has been excluded from the research contribution.

● This dissertation mainly concentrates on assessing natural images degraded by weather degradation. Environmental stimuli include fog, rain, snow, dust, and mist. Rainy image assessment is the main focus area of this dissertation.

● De-raining is another scope of this dissertation, where rain strikes have been removed from the rainy images to retrieve the actual scene.

● Object Detection is another research area addressed in this dissertation.

● The video surveillance system is also incorporated here.

● Medical image processing is another area of research that the dissertation claims to make a novel contribution.

The research contributions addressed in this dissertation have an orientation toward application areas. The application areas, which have been demonstrated using the novel research contribution, are as follows –

● A rainy image detection system has been implemented using a no-reference image quality assessment approach and evaluated with the publicly available dataset.

● A weather classification system has been implemented using full reference image quality assessment and experimented to check the efficiency.

● A blurriness assessment system from the input image using no-reference image quality assessment has been developed.

● An application system to protect against spoofing attacks on hand biometry has been implemented using a no-reference image quality assessment approach.

● The detection of a faulty product in a steel manufacturing company was fabricated using a full-reference image quality assessment approach.

● A System for object detection from rainy scenes captured through a video surveillance camera has been implemented.

● An application system has been built to remove rain strikes from rainy images
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This dissertation's research contributions and application systems have been fabricated using different technological approaches. These approaches are enlisted as follows –

● Statistical analysis of different degrees has been used to implement the different contributions presented in this dissertation.

● Feature engineering is another process used to create applications. A novel feature extraction method has been contributed to this dissertation.

● Standard machine learning algorithms have been used here to develop several application systems for this dissertation.

● A deep learning model, You Only Look Once (YOLO), has been used to detect objects from rainy situations captured through a video surveillance camera.

● Another deep learning model, the Generative Adversarial Network (GAN), has been used to implement the application system to remove rain strikes from rainy images.

The overall contribution of this dissertation can be classified into two segments – the first one is the contribution to the literature on image processing and the second part of the contribution to the application areas of image processing. Contributions to the literature on image processing have been enlisted as follows –

1. No reference image quality assessment metric has been designed to assess the quality of rainy images.
2. Novel metric named No-Reference Image Blurriness Estimation Metric (NIBEM)
3. Novel Spatial feature-based feature extractor algorithm coined as Orientate Intensity Velocity' image descriptor (OIVID)
4. Orientate Intensity Velocity Full Reference Image Quality' (OIVFRIQ) metric

This Thesis contains seven chapters.

Chapter 1 introduces the dissertation. This thesis contains research in the field of Image Quality Assessment. An introductory discussion has been included first in the chapter. The main objective, necessity, and importance of the research domain have been elaborated in this discussion. The reasons behind the degradation of the image have been included. Two main types of degradation have been noted: degradation due to technical reasons and image degradation due to environmental stimuli. This thesis mainly concentrates on the degradation of images due to environmental stimuli. The complete scope of the dissertation has been included in the chapter. The scope of the dissertation has different orientations like research contributions, application orientations, technological orientations, and orientation toward experimental data. The main contribution of the thesis can be found in this chapter. A complete overview of the thesis has been presented in Chapter 1.

Chapter 2 discusses research in the field of image quality assessment found in the literature. The research can be classified into three classes: Full reference Image Quality Assessment (FRIQA), Reduced Reference Image Quality Assessment (RRIQA), and No Reference Image Quality Assessment (NRIQA).

This thesis classifies the research works under FRIQA into three classes: top-down approach, Two-step approach, and CNN-based approach.

Similarly, RRIQA's state-of-the-art research works have been classified into statistical and non-statistical approaches.

Finally, NRIQA works can be classified into two classes - Distortion independent and Distortion specific.

Chapter 3 belongs to the research area of the full-reference image quality assessment. This chapter introduces a novel image descriptor, Oriented Intensity Velocity Image Descriptor (OIVID), by considering image intensity as a vector quantity. This concept has been used in the design of image descriptors for the first time. The novel image descriptor has been evaluated using images of different types and modalities. It has been found that OIVID performs better than the state-of-the-art methods. Then, the image descriptor was applied to the FRIQA task, and

a novel FRIQM named Oriented Intensity Velocity Full-reference-image Quality metric (OIVFQ) was developed. The OIVFQ performs significantly in the prediction of image quality based on the experiments conducted on three standard IQA databases.

Chapter 4 enlightens the research area: No-reference Image Quality Assessment (NRIQA). This chapter introduces a novel image quality assessment metric, the No-Reference Image Blurriness Estimation Metric (NIBEM). This is a no-training-based, no-reference image quality metric that performs the global analysis of image statistics. There are different types of distortions present. Those are - blurring, impulse noise, Additive Gaussian Noise, Special Correlation noise, quantization noise, distortions due to compression, chromatic aberration, etc. In those types of distortions, blurring is the most common type of Distortion. An image can be blurred for many reasons – defocusing of the camera, movement of the acquisition device, the presence of high-intensity light, etc. When a vision is blurred, the variation in intensity values will be below, and objects in the image cannot be adequately separable from the backgrounds. Therefore, the information in the image goes very low. Analyses of those blurred images may lead to erroneous conclusions. Thus, it is crucial to check whether the image is blurred when analyzing it. An image quality metric that can measure the blurriness of an image is beneficial in this regard. The NIBEM is a metric that can assess the blurriness of an image.

Chapter 5 mainly deals with the research on assessing images degraded by environmental stimuli. Rain is one of the most challenging weather conditions that can degrade vision complexly. Therefore, handling rainy images is a very challenging task. Rainy image processing is one of the most critical areas of research contribution. In this chapter, three significant fields of rainy image processing have been discussed. First, the method for assessing the quality of rainy images has been explained, followed by image draining and object detection in rainy images. A novel no-reference image quality metric has been designed to assess the quality of rainy images. That metric helps to identify rainy images. Rain strikes have been removed from the input rainy images in the de-raining task. Object detection from surveillance video in rainy conditions is another part of the chapter. YOLO v3 deep-learning model has been used for this purpose.

Chapter 6 contains some application areas of Image Quality Assessment. This chapter discusses two significant applications: spoofing detection and medical image processing of the IQA. Biometric systems are now used in almost all organizations for authentication purposes. However, the biometric system is always under the threat of spoofing attacks, which are unauthorized attempts to break the security of a biometric system. Spoofing is a very challenging aspect of a biometric system. Therefore, a separate process must be included in the biometric system to protect it from spoofing attacks, and IQA techniques are very applicable to handling such spoofing attacks. A novel spoofing attack prevention technique using the IQA technique for processing has been discussed.

Medical Image processing is an essential area of research related to diagnosing different diseases using different image modalities. IQA has a prominent scope of application in this field. A novel technique to detect breast tumors has been introduced, using the no-reference IQA technique.

This thesis presents an overview of the thesis entitled "Image Quality Assessment of Degraded Natural Images due to Weather Degradation" in brief. The thesis mainly contributes to the research

field, namely Image Quality Assessment. It is a critical area of research in the field of Image Processing. The scope of the dissertation can be found here. Research contributions have been pointed out in the first part of this document. The organization of the thesis has been described here. A very brief summary of the chapters has been included here. Finally, the future direction of the current research is enlisted here.

In this thesis, research contributions are limited to the two approaches – full-reference and no-reference image quality assessment. The reduced-reference approach remains untouched in this dissertation and can be addressed in the future. Along with that, research can be continued on different weather conditions. There is a vast scope of research in this area. The quality assessment for images degraded by various weather conditions is a complex problem, and more research is needed in this domain to explore. Different application domains can be touched using image quality assessment research based on the vast applicability of the research domain. Research on machine learning and deep-learning-based image quality assessment has been conducted. However, these approaches face some problems. Meta-learning is an approach that can be applied in image quality assessment to solve those problems