

# Full-Reference Image Quality Expression via Genetic Programming

Illya Bakurov, Marco Buzzelli, Raimondo Schettini, Mauro Castelli, and Leonardo Vanneschi

**Abstract**—Full-reference image quality measures are a fundamental tool to approximate the human visual system in various applications for digital data management: from retrieval to compression to detection of unauthorized uses. Inspired by both the effectiveness and the simplicity of hand-crafted Structural Similarity Index Measure (SSIM), in this work, we present a framework for the formulation of SSIM-like image quality measures through genetic programming. We explore different terminal sets, defined from the building blocks of structural similarity at different levels of abstraction, and we propose a two-stage genetic optimization that exploits hoist mutation to constrain the complexity of the solutions. Our optimized measures are selected through a cross-dataset validation procedure, which results in superior performance against different versions of structural similarity, measured as correlation with human mean opinion scores. We also demonstrate how, by tuning on specific datasets, it is possible to obtain solutions that are competitive with (or even outperform) more complex image quality measures.

**Index Terms**—image quality, full-reference image quality assessment, image similarity, ssim, genetic programming

## I. INTRODUCTION

Nowadays, digital imaging constitutes a whole new way of communication and, due to technological advancements, creating any sort of digital content and sharing it to a virtual community of millions of people is just a matter of a few clicks and seconds. Such ease of digital content creation also encourages the demand for its efficient management. In this sense, one of the key concepts underpinning numerous digital imaging management techniques is the one of image similarity. Notwithstanding, the concept of similarity is vague and multifaceted, therefore open to different interpretations and definitions: it can be analytically defined with objective criteria, but it can also refer to subjective interpretations. Image similarity can be used to quantify the perceived visual quality of digital images, typically employed in the field of signal compression and telecommunication, serve as the basis for image-based search and image clustering, both useful in the management of personal photo collections and in detecting cases of copyright infringement and use of proprietary content without proper credit. In this study, we focus on the objective means to quantify images' visual quality.

Many aspects influence the perceived visual quality of a digital image or video. For instance, an accidental shake of

the capturing device during the acquisition process can blur the whole image. Likewise, poor lighting conditions can result in images with a low dynamic range and high noise levels. Also, raindrops adhering to a window or camera lens can significantly decrease the performance of scene recognition systems for automotive applications, etc. Moreover, several image processing steps usually occur before the final users can employ the digital imagery. Frequently, these are organized into a sequential set of steps, like digitization, compression, storage, transmission, and reproduction, and may result in a noticeable visual degradation of the output digital imagery. From the perspective of media quality perception, this might result in a sub-optimal viewing experience. In this sense, to better manage the ever-growing digital content (images in particular) and improve users' experience, it becomes necessary to efficiently quantify the perceived visual quality of images. For those types of applications in which humans ultimately view the images, the most appropriate method for images assessment is through the human visual system itself [1], i.e., by involving people to assess images' quality. However, in the context of a digital society where hundreds of millions of photos are being generated and uploaded to social media every day, subjective evaluation becomes impractical as it is time-consuming, expensive, and highly sensible to the experimental design [2]. Considering the aforementioned limitations, several researchers have proposed objective measures that can automatically (i.e., without human involvement) estimate the perceived visual quality as humans would do. These are called image quality assessment measures (IQAMs) and are frequently classified based on the availability of a pristine reference image. When a measure assesses the similarity between a pristine reference image and its degraded variant, it is usually called full-reference IQAM (FR-IQAM). On the other hand, when the reference is not available, the measure is often called no-reference IQAM (NR-IQAM). Moreover, when the reference image is not completely provided (i.e., only some partial information is available, as a given set of the extracted features), the measure is frequently called reduced-reference IQAM (RR-IQAM). Historically, researchers hand-crafted these measures based on their understanding of the human visual system, mathematics, and information theory. One of the most notable is the Structural Similarity Index Measure (SSIM) and its numerous variations [1]. The simplicity of the SSIM formulation resulted in high levels of human interpretability (each component amounting to the final SSIM value can be individually analyzed and assessed), as well as high efficiency.

Following a different direction from the development of

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