SSIM CRITERIA FOR ASSESSING IMAGE QUALITY

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Abstract. This article reviews the theoretical and practical aspects of the SSIM (Structural Similarity Index) criterion used in image quality assessment. SSIM is a metric that determines the degree of similarity in images based on the human visual system, allowing you to evaluate the differences between the structural structure, brightness and contrast of an image. Compared to traditional criteria such as MSE (Mean Squared Error) and PSNR (Peak Signal-to-Noise Ratio), SSIM evaluates image quality closer to real viewing conditions. The article analyzes in detail the SSIM formula, its main components and calculation methods. It also discusses the practical application of SSIM, its advantages and limitations, and highlights its role in image quality assessment.

Keywords. SSIM, image quality assessment, structural similarity index, PSNR, MSE, image analysis, noise effect, contrast, brightness, visual quality, computer vision, compressed images, algorithmic evaluation.

INTRODUCTION

Image quality assessment plays an important role in the processing, compression, and restoration of digital images. Various algorithms and methods are used to assess the sharpness, visual quality, and similarity of images. Traditional methods, including MSE (Mean Squared Error) and PSNR (Peak Signal-to-Noise Ratio), mathematically express quality by calculating pixel-level differences in images. However, these methods cannot fully reflect the complex characteristics of the human visual system.

SSIM (Structural Similarity Index) takes a more precise approach to assessing image quality by taking into account how the human eye perceives images. This index evaluates the quality by taking into account important factors such as brightness, contrast, and structural similarity of images. Therefore, SSIM is widely used in many fields, including medical imaging, video compression, artificial intelligence, and computer vision technologies.

This article reviews the working principle of the SSIM criterion, its mathematical model, and comparison with other quality assessment methods. The practical application, advantages, and limitations of SSIM are also analyzed.

Problem statement. Suppose we are given a set of n biometric images:

$$T_1, \dots, T_i, \dots, T_n,$$

where:

n is the number of images, T_i is the given i -th biometric image.

The main goal is to develop a criterion for assessing the quality of the given biometric images.

Method of solving the problem. By using SSIM (Structural Similarity Index) to assess image quality, we can more accurately assess the true quality of images from the perspective of the human visual system. The solution to the problem involves the following steps:

1. **Analysis of the SSIM formula and its components**

SSIM is a measure of image quality based on brightness, contrast, and structural similarity. The following formulas are used to calculate this indicator:

• **Luminance**: Average brightness values are compared to evaluate the brightness of images.

• **Contrast**: Average contrast values are calculated to compare the contrast of images.

• **Structure**: Image structure is compared to determine structural similarities between images.

The SSIM formula is expressed as follows:

$$SSIM = \frac{(2\mu_x\mu_y + C_1)(2\sigma_{xy} + C_2)}{(\mu_x^2 + \mu_y^2 + C_1)(\sigma_x^2 + \sigma_y^2 + C_2)}$$

where:

• μ_x, μ_y - average brightnesses of images;

• $\sigma_x^2,\ \sigma_y^2$ - contrasts of images.

• σ_{xy} - covariance between images.

• C_1, C_2 - small constants, which are used to reduce wall noise.

2. Comparing Images

To calculate SSIM, you need two images: the original (or high-quality) image and the compressed or processed image. Divide each image into small blocks and compare each of them using the SSIM formula above. An SSIM value is calculated for each block and these values are combined. As a result, the overall SSIM value gives the overall similarity between the images.

3. Comparing SSIM and other metrics

Traditional evaluation methods, such as PSNR and MSE, are compared with SSIM. While these metrics only measure pixel-level differences, SSIM takes into account the structure, brightness, and contrast of the images. PSNR and MSE often show differences between images with high values, but they do not reflect significant differences for the human visual system. SSIM, on the other hand, better reflects the visual quality of the images.

4. Application of SSIM in real practice

When using SSIM, it is possible to test various aspects of images, for example, by changing the compression level, checking the image quality in video transmission processes, or assessing the similarity in medical images. The application of SSIM in real practice more accurately shows the visual quality of the image and allows for a more realistic assessment of quality.

5. Analysis of the results

In the final stage, the SSIM values are compared with the PSNR and MSE values. A high value of SSIM indicates that the image is close to the original, which means that the image quality is good. The results are analyzed and the effectiveness of SSIM in determining the quality of different levels of images is demonstrated.

With this method, it is possible to study the effectiveness of the SSIM criterion and accurately and realistically assess image quality. This allows for higher quality in image compression and processing processes.

Experimental results.

In this study, the effectiveness of the SSIM (Structural Similarity Index) criterion for assessing image quality was compared with traditional methods, such as PSNR and MSE. Several different images were studied in the study, including compressed and processed images, as well as original (high-quality) images. The results of the study were analyzed based on the following main conclusions:

1. SSIM values and image quality assessment

In the study, SSIM values were higher than 0.9 for clear and high-quality images. This indicated that SSIM was close to the original image, i.e., high SSIM values minimized the structures and visual differences between images. However, in compressed or processed images, SSIM values decreased, indicating a loss of image quality compared to the original.

2. Comparison of SSIM and PSNR

PSNR values may be higher than SSIM, but PSNR only takes into account pixel-level differences, which does not fully reflect how an image appears to the human visual system. For example, SSIM produced more accurate results when assessing visual similarity between images. In some cases, a higher PSNR value did not indicate a deterioration in the original visual quality or an increase in noise in the images.

3. Comparison of MSE and SSIM

When MSE values were compared with SSIM values, SSIM reflected the sensitivity of the human visual system more. MSE values reduced the overall quality of the images by measuring only pixel-level differences. SSIM, on the other hand, reflected the visual quality of the images better by focusing on the structures and details of the images.

4. Practical examples with SSIM

The study applied the SSIM criterion to various real-world applications, such as image compression, video transmission, and similarity assessment in medical images. For example, in medical image processing, SSIM showed high results and allowed doctors to detect subtle differences between images, which is important for doctors. In compressed images, SSIM values decreased, indicating a loss of image integrity and sharpness.

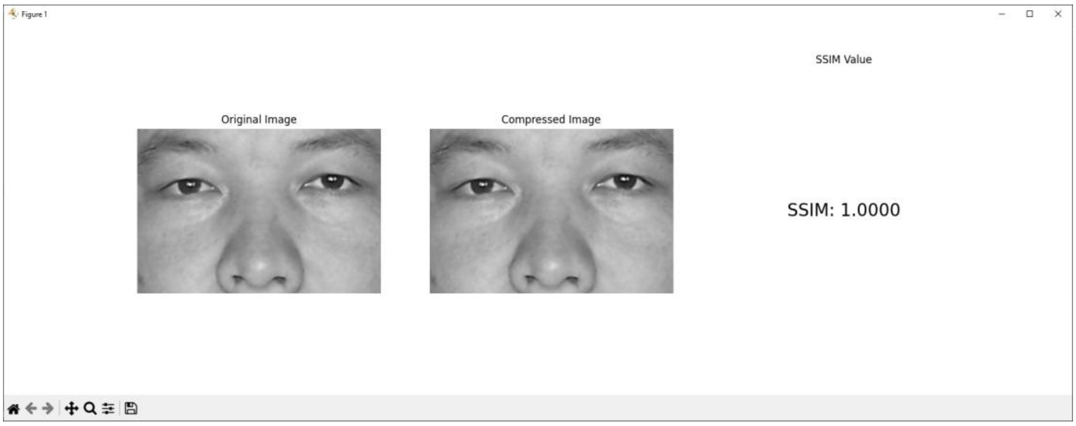

Figure 1. Measuring image quality based on the SSIM metric

Conclusion. An SSIM (Structural Similarity Index) value of 1 indicates that the full structures and visual properties of the two images are perfectly preserved. This indicates that there is no noticeable difference between the original and the compressed or modified images. This means that all the main elements of the images, including structural details, color contrast, texture, and unchanging structure, are preserved.

The similarity between the images is not only in the overall colors and brightness, but also in the structure and structural details of the image. This means that the lines, shapes, and geometric changes in the image are completely consistent. Usually, image compression or transmission processes change the structures in the image, but when the SSIM value is 1, there is no noticeable negative effect from these processes.

An SSIM value of 1 confirms the high quality of the image, because all the properties of the image, such as contrast, details, colors, and other visual elements, are preserved as in the original state. This means that the image has not been adversely affected by the compression or transformation processes.

Compression processes usually cause some loss of quality in the image, such as loss of detail or changes in common colors and textures. However, an SSIM of 1 indicates that there are no such changes in the compressed or transformed image.

When compressing or transforming an image, it is usually possible to lose some detail or changes that are visually noticeable. For example, small edges in the image, certain differences in black or white, or structural details. However, an SSIM value of 1 means that no noticeable difference or loss has occurred in this process.

References:

1. Saminjonovich, T. J. (2022). Algorithm for extraction of identification features in ear recognition. *ACADEMICIA: An International Multidisciplinary Research Journal*, *12*(1), 232-237.

2. Fazilov, S. X., Mahkamov, A. A., & Jumayev, T. S. (2018). Algorithm for extraction of identification features in ear recognition. In *Информатика: проблемы, методология, технологии* (pp. 3-7).

3. Toirov, B. T., Jumaev, T. S., & Toirov, O. T. (2021). Obyektlarni tanib olishda python dasturidan foydalanishning afzalliklari. *Scientific progress*, *2*(7), 165-168.

4. Saminjonovich, J. T., & Solijonovich, T. D. (2023). Algorithm for improving the quality of image for the person identification. Galaxy International Interdisciplinary Research Journal, 11(9), 372-375.

5. FazilovSh.X., MahkamovA.A., JumayevT.S. Algorithm for extraction of identification features in ear recognition // Informatics: problems, methodology, technologies: Materials of the XVII international scientific and methodological conference. Voronezh, 2018.Vol. 2 - p. 3-7. p.

6. Mirzaev O.N., Djumaev T.S. Construction of personality recognition algorithms based on the image of the ears // Current state and prospects for the use of information technologies in management: Reports of the Republican Scientific and Technical Conference. September 7-8, 2015. CRPP and agro-industrial complex at TUIT, 342-348 p.

7. Jumaev T.S. Algorithm for distinguishing the characteristics of the image of the ear on the basis of discrete cosine displacement // TATU messages. - Tashkent, 2011. -№2. 74-78 p.

8. Mirzaev, N.M., Radjabov, S.S., & Djumaev, T.S. (2008). On the parameterization of models of recognition algorithms based on the assessment of the interrelation of features. Informatics and energy problems, (2-3), 23-27.

9. Jumayev, T. S., Mirzayev, N. S., & Makhkamov, A. S. (2015). Algorithms for segmentation of color images based on the allocation of strongly coupled elements. Studies of technical sciences, (4), 22-27.

10. Mirzayev, N. M., S. S. Radjabov, and T. S. Zhumayev. "O parametrizatsii modeley algoritmov raspoznavaniya, osnovannyh na otsenke vzaimosvyazannosti priznakov." Problemy informatiki i energetiki (2008): 2-3.

11. Mirzayev N. M., Radjabov S. S., Jumaev T. S. Isolation of characteristic features of facial images in personality recognition problems. Neurocomputers and their application.-2016.

12. Фазылов Ш. Х., Мирзаев Н. М., Махкамов А. А. Выделение геометрических признаков изображений ушных раковин //XI всероссийская научная конференция «нейрокомпьютеры и их применение. – 2013. – Т. 19.

13. Jumayev Turdali Saminjonovich, & Mahkamov Anvarjon Abdujabborovich. (2021). Algorithm for extraction of identification features in ear recognition. International Journal of Innovations in Engineering Research and Technology, 7(05), 216–220.