Image Resolution Enhancement in Underwater Applications

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***Abstract* — The necessity to improve image resolution is of great concern in multiple diverse fields such as: medicine, communications, or satellite and underwater applications. A high variety of techniques for image enhancement has been proposed in the literature; nevertheless it is necessary to fairly validate this improvement effectively. This work is focused on a test environment that permits to objectively compare the quality enhancement of underwater images processed by two different improvement methods: bilinear interpolation and Super-Resolution (SR), showing that the proposed SR algorithm performs relatively well in this particular scenario. The quantitative comparison is based on the PSNR (Peak Signal-to-Noise Ratio) and the SSIM (Structural SIMilarity) index.**

Keywords — Underwater applications, image enhancement, Super-Resolution, test bench.

I. INTRODUCTION

In some scenarios, such as satellite or underwater imagery, it is difficult to use high resolution sensors due to physical constraints. A way to address this problem is to accept the image degradations and use signal processing techniques to post-process the captured images; one of these techniques is referred to as Super-Resolution (SR) reconstruction. The used approach for Super-Resolution (SR) in this paper is to construct High-Resolution (HR) images from several observed Low-Resolution (LR) images, thereby increasing the high-frequency components and removing the degradations caused by the imaging process of the LR camera. A characterization environment is necessary to compare alternative methods to improve image resolution [1]. The work presented in this paper is focused on the development of a testbench used to compare the results obtained from the application of a bilinear interpolation and an alternative proprietary method developed for image improvement with the aim of evaluating the feasibility of SR to the enhancement of underwater images. This test bench will provide information about the best SR parameters that will maximize underwater real sequences.

II. RELATED WORKS

Model-based SR reconstruction techniques for underwater imaging have been previously studied. Some works [2, 3], use the PSNR (*Peak Signal to Noise Ratio*) in order to compare the bilinear interpolated image with the super-resolved one. On the contrary, in [4], Pezham Firoozfam uses the RMSE (*Root Mean Squared Error*) to compare different turbidity levels in terms of Nephelometric Turbidity Units (NTU), and the SSIM (Structural SIMilarity) index is introduced in [5]. After evaluating all these metrics, it was detected that PSNR and SSIM are extensively used. Consequently it was decided to use both of them as a basis for the proposed test bench.

III. SUPER-RESOLUTION ALGORITHM

The SR algorithm that has been used and tested in this work is based on [6] and belongs to the *fusion* category. Specifically, it is a non-iterative dynamic SR algorithm, which reduces the computational cost and memory requirements. One of its particularities is that it provides both *static* and *dynamic* SR, depending only if one high resolution output frame, or a sequence of frames, is obtained as a result.

IV. PROPOSED TEST BENCH

In order to set up a validation environment for the proposed image quality enhancement method, a test bench has been developed. It is based on the fact that a LR input sequence is necessary to perform the SR process. Therefore, if the process to be tested is the SR method, firstly a LR sequence is obtained from a HR input sequence. Then, the LR sequence is super-resolved, and, at the same time, a bilinear interpolation is applied for comparing their results with the super-resolved sequence. However, the test bench, which is shown in Figure 1 is flexible, so its configuration can be modified to adapt to any other image enhancement method.

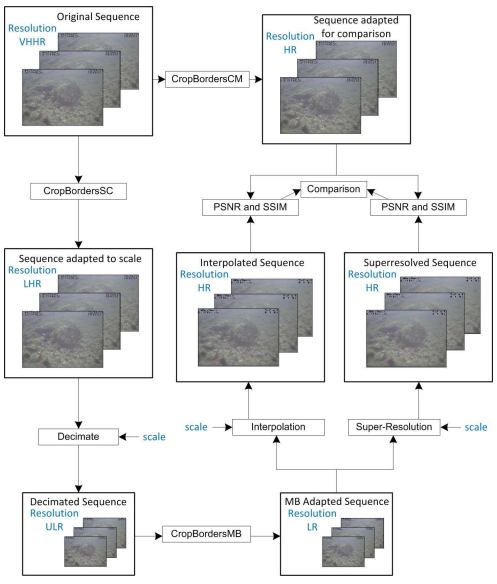

Figure 1. Proposed test bench

V. RESULTS

In this section, the original sequences and the super-resolved sequences are showed to compare them, both objectively and subjectively against the interpolated image. In this work, underwater sequences have been used to validate the proposed test bench, as some of them have been given by the organization "*Oceanic Platform of the Canary Islands*" [7], providing several videos of a campaign promoted for environmental purposes. These videos usually show deficient quality and inadequate characteristics as a consequence of the limits in the used equipment.

Three different underwater sequences, taken from the Internet and the database of the Oceanic Platform of the Canary Islands, were selected due to their characteristics. In all cases, the presented results are given for the optimum selection of parameters, and all of them have shown better results for SR than for interpolation, for both metrics: PSNR and SSIM. Figure 2 shows a composition of all SR parameters to make a decision of the best approach in the sequence "*rocks*", while Figure 3 show the comparison between the interpolated sequence and the super-resolved one.

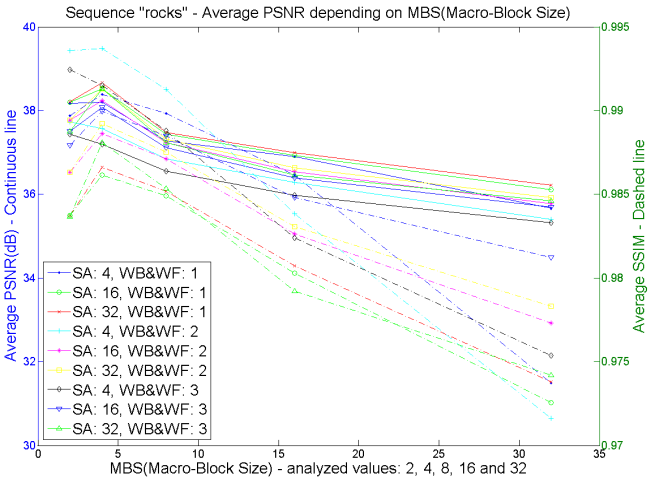

Figure 2. Average objective quality metrics results (complete sequence)

VI. CONCLUSIONS

The proposed test environment shows considerable flexibility on behalf of comparing methods for quality image improvement. Providing the output images and the associated metrics, two alternatives are presented, one objective and the other subjective with the purpose of evaluating the quality of the images. In both cases and for sequences with different characteristics the SR approach has shown better results in the underwater quality image assessment. A detailed study of the best performance depending on the parameters selection has been executed in order to provide the best results that the proposed SR algorithm can achieve.

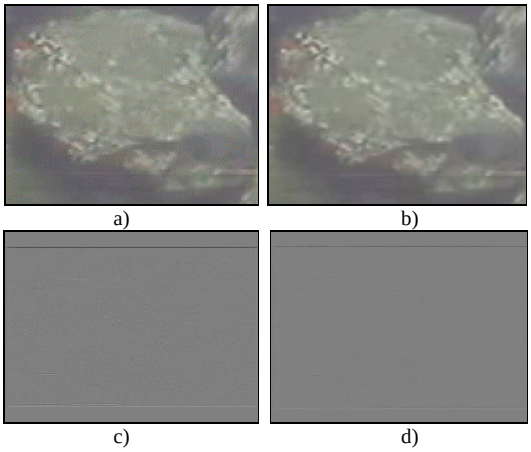

Figure 3. Central rocks detail – a) Interpolation, b) Super-Resolution, c) Difference original-interpolated, d) Difference original-superresolved

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