



Article Hair Removal Combining Saliency, Shape and Color

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Featured Application: Hair removal is a preliminary and often necessary step in the automatic processing of dermoscopic images since hair can negatively affect or compromise the distinction of a lesion region from the normal surrounding healthy skin. A featured application is skin lesion segmentation.

Abstract: In a computer-aided system for skin cancer diagnosis, hair removal is one of the main challenges to face before applying a process of automatic skin lesion segmentation and classification. In this paper, we propose a straightforward method to detect and remove hair from dermoscopic images. Preliminarily, the regions to consider as candidate hair regions and the border/corner components located on the image frame are automatically detected. Then, the hair regions are determined using information regarding the saliency, shape and image colors. Finally, the detected hair regions are restored by a simple inpainting method. The method is evaluated on a publicly available dataset, comprising 340 images in total, extracted from two commonly used public databases, and on an available specific dataset including 13 images already used by other authors for evaluation and comparison purposes. We propose also a method for qualitative and quantitative evaluation of a hair removal method. The results of the evaluation are promising as the detection of the hair regions is accurate, and the performance results are satisfactory in comparison to other existing hair removal methods.

Keywords: dermoscopy; dermoscopic image; skin lesion; lesion segmentation; pre-processing; artifact removal; hair removal; shape; saliency; color space

1. Introduction

In almost every specialist area of medicine, including dermatology, image analysis is transforming the diagnostic methods. In particular, computer-aided diagnosis systems for dermoscopic images have proven to be useful tools to improve significantly the common dermoscopic diagnostic practice, which is usually characterized by limited accuracy and is mainly based on visual inspection. Indeed, to differentiate melanoma from other pigmented skin lesions, these systems display morphological features not easily perceptible by the naked eye and support the assessment process of the human expert [1,2]. Typically, a computer-aided system is structured in four main consecutive steps: preprocessing, segmentation, feature extraction, and classification, each playing a key role in enabling correct diagnosis [3]. During the preprocessing, the dermoscopic image is subjected to noise removal, image enhancement, color quantization, and artifacts removal processes [4,5]. Noise removal and image enhancement techniques are employed to minimize the effects due to different illumination conditions and poor resolution of the acquisition process [6]. Color quantization [7-10] is a technique of reducing the total number of unique colors in the image often used as a preprocessing step for many applications that are carried out more efficiently on a numerically smaller color set. For example, color quantization is employed effectively as a preliminary computation phase for skin lesion segmentation [11–15]. The removal methods of artifacts, such as bubbles, hair, shadows and reflections, aims to eliminate their negative effect and disturbance on the diagnostic operations of the area of interest (i.e., the skin lesion) [16]. Particularly, if the area of the skin lesion is partially



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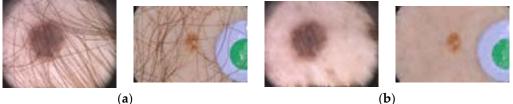
obtained in the three previous steps, are related mainly to how the initial candidate hair components are considered (see Section 2 for more details). In the last step, hair removal is performed using a standard inpainting method.

The method is evaluated and compared extensively with other existing methods Appl. Sci. 2021, 11, since a detailed quantitative and qualitative analysis on two publicly available databases PH² [28] and ISIC2016 [29], usually used in dermoscopic image processing, is performed

The experimental results confirm (a) the effectiveness and the utility of the employ-

ment of saliency, shape, and color information for HR; (b) that HR-SSC achieves good quantitative results with an the date of the study of the formance conceining bit presenting one major challenges for astomatic image analysis method such as ple and rather fast stince it does not require a large amount of computational (HR) methods and skin lesion on a high number of parameters and of large diversity correlated. Usually, SLS methods can determine the

Additional contributions of the left diaming images: Additional contributions of the left diaming images: can include explicitly or implicitly hair removal operations. However, it is appropriate to to be used for testing and comparing each new method; (b) the proposal of a method for qualitative and quantitative evaluation of an FIR method. The paper is organized as follows: In Section 2, we describe the method ffrequencies the efficiency tailing its main steps; in Section 3, we provide a quantitative and qualitative evaluations, especially when there is a massive presence of hair (see Figure 1); (c) for tailing its main steps; also highlighting the provide a quantitative evaluation of experimental results, also highlighting the pros and cons; finally, discussion and conclu-to the expert.



(a)



Figure 1. (a) iguna bloo) Examples (1) 11000 gen (1) 11000 002875) Gillo (2873) sivily represented in the second of the second se the application of patients and the opplication of patients the patients of the patient of the p

2. The Proposed Methaddress the hair issue, several hair removal methods have been proposed. HR The proposed hoch usually remains of two steps: (a) the detection of oscillating hair and generation visual saliency, of the hair binney mask (b) the removal of the detected hair elever ally hair detection is accomplished through object detection methods enucleating thin items, while hair removal is obtained through standard inpainting methods. As reported in [17], at least six main hair removal methods are widely used in the literature [18–23].

The method proposed in [18] by Lee et al., also known as Dullrazor, consists of four steps. The hair regions are initially detected through the morphological closing operator on each RGB color channel separately and with three structuring elements having different directions (step 1). To generate the binary mask, a thresholding process is applied to the absolute difference between the original color channel and the image generated by the closing (step 2). The mask pixels undergo a bilinear interpolation between two nearby not-mask pixels (step 3). Finally, to the resulting image, an adaptive median filter is applied (step 4).

The method [19] by Xie et al. also consists of four steps. The hair area is improved using a morphological closing top-hat operator (step 1). The binary image is obtained through a statistical thresholding process (step 2). To extract the hairs, the elongate feature property of connected regions is employed (step 3). To restore the information occluded by the hair, they apply the image inpainting method based on partial differential equation (PDE), which realizes the diffusion of information through the difference between pixels (step 4).

In the method proposed in [20] by Abbas et al., there are three computational steps. In the CIELab uniform color space, the hairs are detected by a derivative of Gaussian (DoG) (step 1). Morphological techniques to link broken hair segments, eliminate small and circular objects, and fill the gaps between lines are applied (step 2). The adopted inpainting method is based on coherence transport (step 3).

The method in [21] by Huang et al. comprises three steps. To the grayscale version of the image, a multiscale curvilinear matched filter is applied (step 1). To detect the hair regions, hysteresis thresholding is employed (step 2). Then, region growing and the linear discriminant analysis (LDA) technique, based on the pixel color information in the CIELab color space, are applied to recover the missing information left by the removed hair (step 3).

The method [22] by Toossi et al. includes four steps. The image is converted to a grayscale image via a principal component analysis (PCA), and the noise is filtered with a Wiener filter (step 1). Hair is detected by using an adaptive canny edge detector (step 2). A refining process with morphological operators to eliminate unwanted objects and obtain a smooth hair mask is then applied (step 3). The inpainting process is carried out by a multi-resolution transport inpainting method based on wavelets (step 4).

As with [20,21], in [23] by Bibiloni et al., hair removal is made up of three steps. The contrast of the luminance of the image is improved with the Contrast Limited Adaptive Histogram Equalization (CLAHE) algorithm (step 1). The hair is detected using soft color morphology operators in the CIELab color space (step 2). The inpainting phase is based on the arithmetic mean of the modified opening and closing morphological transformations to recover the missing pixels (step 3). The common element of these HR methods and most of the other existing methods, e.g., [24,25], is the employment of morphological operations and, to a minor extent, of information derived from color. On the other hand, although deep learning has been used successfully to solve many difficult computer vision problems, inexplicably, to the best of our knowledge, only two very recent HR methods relying on neural network architecture exist [26,27].

Despite the sufficiently wide variety of the existing papers, the problem of hair removal results to be not solved satisfactorily yet. The main critical points are the failure to identify hair accurately and the undesirable effects such as unremoved thin hair and color alteration.

We address the HR problem using information regarding the saliency, shape, and color of the image objects. These are three elements that have proved to be extremely useful because each of them allows capturing a fundamental aspect of the problem at hand. Indeed, besides the shape aspects, detectable by mathematical morphology properties, it is also appropriate to perform the hair detection based on information related to the significant image elements and detectable by their saliency and color properties. In the following, we refer to the proposed method as saliency shape color for hair removal, shortly indicated as HR-SSC or simply SSC.

As described in Section 2, HR-SSC consists of five steps. The core of the method is step 4, named hair object detection, in which the hair regions are determined. The innovative elements of this step, whose success also depends on the correctness of the results obtained in the three previous steps, are related mainly to how the initial candidate hair components are considered (see Section 2 for more details). In the last step, hair removal is performed using a standard inpainting method.

The method is evaluated and compared extensively with other existing methods since a detailed quantitative and qualitative analysis on two publicly available databases PH² [28] and ISIC2016 [29], usually used in dermoscopic image processing, is performed.

The experimental results confirm (a) the effectiveness and the utility of the employment of saliency, shape, and color information for HR; (b) that HR-SSC achieves good quantitative results with an adequate balance and has a competitive and satisfactory performance concerning other existing HR methods; (c) that HR-SSC implementation is simple and rather fast since it does not require a large amount of computational power based on a high number of parameters and of labeled training images.

Additional contributions of this work are (a) the availability of appropriate datasets to be used for testing and comparing each new method; (b) the proposal of a method for qualitative and quantitative evaluation of an HR method.

The paper is organized as follows: in Section 2, we describe the method HR-SSC, detailing its main steps; in Section 3, we provide a quantitative and qualitative evaluation of experimental results, also highlighting the pros and cons; finally, discussion and conclusions are drawn in Section 4.

2. The Proposed Method

The proposed method, as mentioned above, is based on three elements: the notion of visual saliency, shape, and color. Indeed, since the saliency of an item is the element

Appl. Sci. 2021, 11, 447

value. The connected components of SM including pixels of the image frame are considered as border components and stored in the bidimensional array, named $B\mathcal{G}_{of 28}$

Moreover, the image corner components, usually much darker than the image center, are detected following the same procedure proposed in [34]. Specifically, the representa-

tion of the input image in the HSV color space is examined: the channel V undergoes a for it stands out from its neighbors [30], its use allows to enucleate the most relevant thresholding process by a predefined threshold value δ . Then, the components of the subsets and to focus on the hair regions especially. Moreover, since hair regions have a thresholded V covering most of the frame or the corner area of the image are considered well-defined structure, the shape-oriented operations of the mathematical morphology, that simplify image data, preserving their essential shape characteristics and ethimating interevancies" [31], lend themselves well to detect the hair object. On the other hand, **Step4** of the correction of the frame or result essential to distinguish between no-hair stored in the bidimensional array, the no-hair regions are detected and hair regions when information result essential to distinguish between no-hair and hair regions when information result of safetier of the safetier of the safetier of the safetier of the ambifuence of the corner area of the safetier of the safetier of the safetier of the safetier of the stored in the bidimensional array of the safetier of the safetier of the safetier of the ambifuence of the corner area of the safetier of the s

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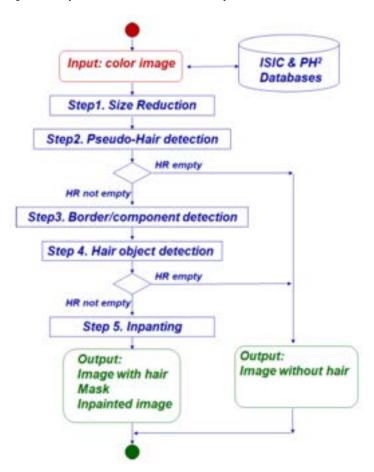


Figure 2. Withwith the PIRE proposed method (HR-SSC).

- **Step 1. Size reduction**—The first step is devoted to limit the computation burden of the successive steps by reducing the size of the input image with a scale factor *s* equal to the ratio of a fixed value, say *Maxdim*, and the number of columns. To perform this, we resort to the classical and most common bicubic downsampling, implemented by the Matlab command *imresize* with bicubic option and scale factor *s*. The size reduction step is an optional but highly recommended operation since it significantly limits the computation time.
- Step 2. Pseudo-Hair detection—This step is based on top-hat transformation, i.e., a morphological operator capable of extracting small elements and details from

a grayscale image, commonly used for feature extraction, background equalization, and other enhancement operations. There are two types of transformation: the white top-hat transformation, defined as the difference between the original image and its aperture by a structuring element, and the black top-hat transformation (or bottom-hat transformation), defined dually as the difference between the closure by a structuring element and the original image [32,33]. Following [19,34], to obtain the binarized version HR initially containing the pseudo-hair components, we apply a bottom-hat filter in the red band R of the RGB image and then the Otsu threshold method [35] by the Matlab command *imbinarize*. Then, if HR is not empty, the actual hair regions are determined during the successive steps 3–5.

Indeed, the components currently detected in HR (i.e., the so-called pseudo-hair components) can correspond to hair regions but can also correspond to portions of other types of artifacts survived this preliminary treatment, such as marker ink signs, dark spots belonging to the lesion, marker colored disks [34], and regions wrongly identified. These regions not corresponding to hair regions are called no-hair regions in the following, and if they exist, they are detected and eliminated in the successive steps. In Figure 3b some examples of pseudo-hair are shown, where the no-hair regions are approximatively indicated by a red arrow.

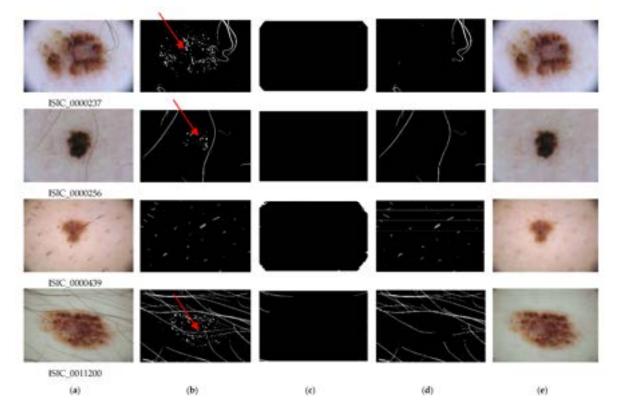


Figure 3. Some examples of results obtained in the main steps of HR-SSC: (**a**) input image; (**b**) detected pseudo-hair components; (**c**) border/corner components; (**d**) detected hair; (**e**) resulting image.

Step 3. Border and corner component detection—The border components are detected based on their saliency and proximity to the image frame, by applying the following process, named called border detection, already used in [14,15]. The saliency map (SM) with well-defined boundaries of salient objects is computed by the method proposed in [36]. Successively, SM is enhanced by increasing the contrast in the following way: the values of the input intensity image are mapped to new values obtained by saturating the bottom 1% and the top 1% of all pixel values, by the Matlab command *imadjust*. Then, the saliency map SM is binarized by as-

signing to the foreground all pixels with a saliency value greater than the average saliency value. The connected components of SM including pixels of the image frame are considered as border components and stored in the bidimensional array, named BC.

Moreover, the image corner components, usually much darker than the image center, are detected following the same procedure proposed in [34]. Specifically, the representation of the input image in the HSV color space is examined; the channel V undergoes a thresholding process by a predefined threshold value δ . Then, the components of the thresholded V covering most of the frame or the corner area of the image are considered as image corner components and are stored in the bidimensional array, named CC (see Figure 3c).

Step 4. Hair object detection—Preliminarily, the no-hair regions are detected and stored in the bidimensional array, named NR, as follows. NR is initially computed as the product S.*V and binarized by the Otsu method. Then, the salient pixels not belonging to HR and BC are included in NR, the pseudo-hair regions currently detected in HR are removed from NR, and small holes in NR are filled. Successively, if NR has a significant extension (area), the detected no-hair regions are removed from HR. If the current HR is not empty, border components are suitably considered and possibly removed from HR taking also into account the gray version of the input image Ig and a fixed gray value, say Δ , indicating a minimum reference gray value for the hair component. Finally, corner components and eventual remaining components corresponding to colored disks are eliminated from HR.

At the end of this step, the regions in HR are located in correspondence with the detected hair objects and form a binary hair-mask on which to perform the next reconstruction step. See the Matlab pseudocode given below for more details. In Figure 3d, examples of detected hair are given.

Step 4. Hair object detection

% No-hair regions detection NR = S. *V; % Initial no-hair regions construction and storing in NR NR = imbinarize(NR, graythresh (NR)) % Otsu binarization NR(SM > 0 & HR == 0 & BC == 0) = 1; % insertion in NR of salient pixel not belonging to HR and BC NR (HR > 0) = 0; % pseudo-hair elimination from NR NR = imfill(NR,'holes'); % holes filling % end of no-hair regions detection if (area(NR) is significant) HR(NR > 0) = 0; % no-hair regions removal from HRHR = imfill(HR,'holes'); % holes filling if (HR is not empty) if (BC is not empty) % border and corner components management NB = BC; % copy of BCNB(NR > 0 & Ig > Δ) =0; % generation of NB without no-hair regions and too dark regions $HR(NB \ge 0 \& SM \ge 0) \%$ elimination of salient pixels of NB from HR CR = (BC > 0 & NB > 0) % common regions to BC and NB HR(CR > 0) = 0 % elimination from HR of common regions of BC and NB CR(CR > 0 & CC > 0) = 0; % corner regions elimination from CR BN = border_detection (CR); % border components detection in CR (as done in step 3) if (BN is not empty) $HR(BN > 0 \& Ig > \Delta) = 0$; % elimination of clear border regions of CR from HR end end $HR(NR > 0 \& HR > 0 | (BC > 0 \& Ig > \Delta)) = 0$; % colored disk and clear border component removal end end

Step 5. Inpainting and rescaling—If HR is empty, the image is considered hairless; otherwise, the reconstruction process is applied. After a preliminary enlargement of HR by n steps of dilation, the inpainting is carried out by calling the Matlab function *regionfill* on each image channel separately, by using HR as hair-mask and then joining the resulting channels. If the size reduction step has been performed, a scaling is newly applied using the Matlab function *imresize* with the bicubic option. In Figure 3e, examples of the resulting image are given.

Different parameter settings to achieve a trade-off between quality and performance have been explored. The better parameter values resulting from this analysis are *Maxdim* = 500, $\delta = 0.4$, $\Delta = 100$, n = 3. The experimental results shown in this paper are obtained by this setting. The method is implemented in Matlab using Intel[®] core TM i7—6600U CPU 2.60 GHz with 8 GB installed RAM and a 64-bit Operating System Windows 10.

3. Experimental Results

This section describes the image datasets and the evaluation of the experimental results in qualitative and quantitative terms. In fact, the evaluation of the performance of the proposed method and the comparison with other methods are very hard tasks due to the lack of publicly available source code of the existing methods, the limited literature, and the different evaluation methodology often employing not well-specified datasets and different quality measures. To overcome these critical issues, (a) we select some adequate datasets (see Section 3.1); (b) we perform qualitative evaluations/comparisons from different points of view (see Section 3.2); (c) following [17,37], we perform quantitative evaluations and comparisons by generating synthetic hair on skin lesion images originally hair-free in a controlled way (see Section 3.3). Note that the controlled hair introduction modality offers the advantage that the added hair regions are known and constituted a reference image, i.e., a ground truth. Accordingly, since the quantitative evaluation of the performance of an HR method requires a reference image, this modality is the unique way to evaluate the results by comparing the added hair regions in the reference image (ground truth) with the detected hair regions in the binary mask.

3.1. Datasets

We test our method by considering images available on two publicly available databases of dermoscopic images: PH² [28] and ISIC2016 [29]. PH² is a dermoscopic image database acquired at the Dermatology Service of Hospital Pedro Hispano to support comparative studies on segmentation/classification methods. This database includes clinical/histological diagnosis, medical annotation, and the evaluation of many dermoscopic criteria. It provides 200 dermoscopic RGB images and the corresponding ground truth, including 80 atypical nevi, 80 common nevi, and 40 melanomas. All the images are 8-bit RGB and have resolution 760×560 pixels. ISIC2016 is one of the largest databases of dermoscopic images of skin lesions with quality control held by the International Symposium on Biomedical Imaging (ISBI) to improve melanoma diagnosis. It includes images representative of both benign and malignant skin lesions. For each image, the ground truth is also available. ISIC2016 consists of 397 (75 melanomas) and 900 (173 melanomas) annotated images as testing and training data, respectively. The images are 8-bit RGB and have a size ranging from 542×718 to 2848×4288 . PH² and ISIC2016 databases contain numerous images with complex backgrounds and complicated skin conditions with the presence of hair and other artifacts/aberrations.

Since in PH² and ISIC2016 hairless and hairy images are not distinguished, it is not possible to evaluate the performance of an HR method on each total dataset, and it is necessary to separate them preliminarily. Hence, from PH² and ISIC2016 we extract two datasets, denoted as *H*-data and *NH*-data, each constituted by 170 images, which respectively contain images with evident hair and images without hair. These images are selected randomly and subdivided into the two datasets according to a human visual

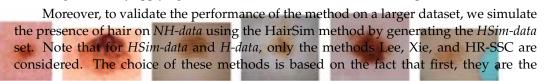
inspection. These datasets, totally comprising 340 images, are available at the Github link indicated in the section Data Availability Statement.

To accurately and comprehensively validate the goodness of detecting hair and, at the same time, to make a deeper comparison with the published results of the existing methods [18–23], which in the following we indicate with the name of the first author (i.e., Lee, Xie, Huang, Abbas, Toossi, Bibiloni), we also consider a specific dataset available in [37]. This dataset, here call *NH13-data* and shown in Figure 4, is constituted by 13 images without hair. We consider also the hairy images obtained starting from *NH13-data* by the GAN method [38] and HairSim method [39], that starting from a hair-free dermoscopic image, provide a hair occluded image and the corresponding hinary hair mack. There

Appl. Sci. 2021, 11, x FOR PEER REVIIMAGE, provide a hair-occluded image and the corresponding binary hair-mask. These are available in [37], are denoted as H13GAN-data and H13Sim-data, and are sho in Figures 5 and 6, respectively. IMD010 IMD017 IMD018 IMD030 IMD006 **IMD019** IMD020 IMD050 IMD061 IMD63 IMD033 IMD044 IMD75 Figure 4: Image dataset NFT3-data proposed in [37]: IMD010 IMD017 **IMD018** IMD030 IMD019 IMD020 IMD006 IMD033 IMD050 IMD63 IMD75 IMD044 IMD061 Figure 5: Image dataset H13CAN-data generated by applying the CAN method (38) to NH13-data and published in (37): IMD010 IMD017 **IMD018** IMD006 **IMD019 IMD020** IMD030

Figure 8. Image dataset H13Sim-data generated by applying the HairSim method 1391 to NH13-data and published in 1631.

IMD061



IMD63

ISIC_0000040

IMD033



ISIC_000096 1

IMD044

ISIC_0000184

IMD050

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Figure 6. Image dataset H13 bink tata yon out the passibility of rangarisen by 9596 with 95 and published in [37].

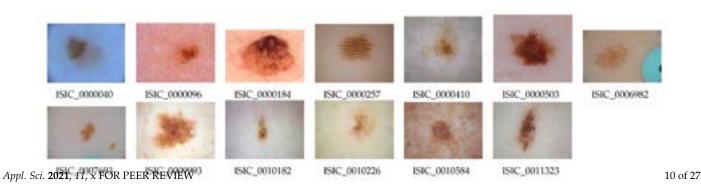


Figure 7: Image dataset sNH-data selected randomly from NH-data:

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Figure 8. Image datasets Historiata with the hair mask produced by applying the HairSim method to sNH-data.

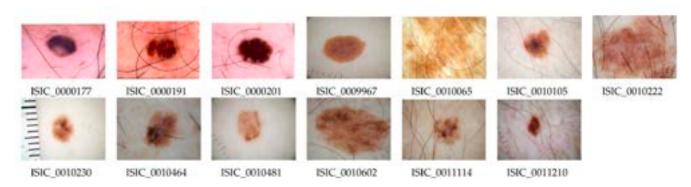


Figure 9. Image dataset *sH-data* selected randomly from *H-data*.

In regard to the assessment of point (a), we find that the classification error is within 25%, 65%, 10%, respectively, for Lee, Xie, and HR-SSC. As concerns the assessment of



Figure 8. Image dataset *sHSim-data* with the hair mask produced by applying the HairSim method to *sNH-data*.

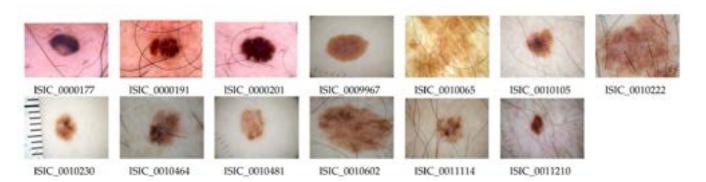


Figure 9. Image dataset *sH-data* selected randomly from *H-data*. Figure 9. Image dataset *sH-data* selected randomly from *H-data*.

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25%, 65%, 10%, respectively, for Lee, Xie, and HR-SSC. As concerns the assessment of point (b), the visual inspection of the results shows that the resulting perceptual quality is in accordance with the percentages obtained for point (a). To verify the effectiveness of the hair removal methods, a recent SLS method [14,15] is applied. The segmentation results show that hair removal applied before the segmentation process involves an improvement of about 70%, 20%, 90% for Lee, Xie, and HR-SSC, respectively. The results of the visual comparison on the various datasets of point (c) are given in Figures 10 and 11 on *H13GAN-data* and *H13Sim-data*, respectively. To give major visual evidence and to facilitate the comparison, in Figures 12 and 13, the results on *sHSim-data* and the corresponding final mask are respectively shown. The same is true for Figures 14 and 15, where results on *H-data* with the corresponding final mask are shown.

In summary, in relation to the qualitative evaluation, from the visual examination of the resulting images of each method available in [37] and HR-SSC on *H13GAN-data* and *H13Sim-data* (see Figures 10 and 11), it appears that evident hair regions are not detected by Abbas and Toossi. Limiting the comparison only to the three methods of Lee, Xie, and HR-SSC, evident hair regions are not detected by Xie on the *HSim-data* and, to a lesser extent, on *H-data*. See the results on the sample *sHsim-data* in Figure 12 and on the sample *sH-data* in Figure 14. Note that HR-SSC is able also to remove the ruler marks that can be mistaken as hair (see Figures 14 and 15).

Appl. Sci. 2021, 11, 447

sH-data in Figure 14. Note that HR-SSC is able also to remove the ruler marks that the mistaken as hair (see Figures 14 and 15).

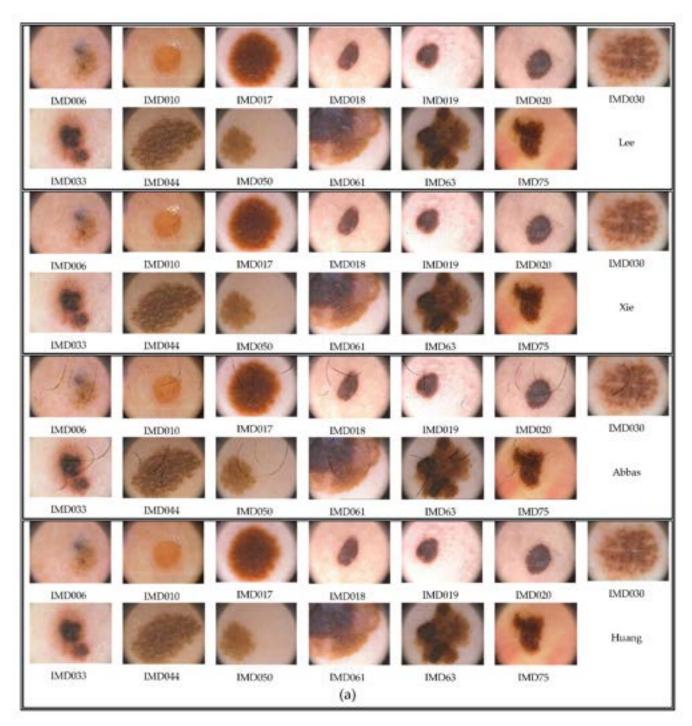


Figure 10. Cont.

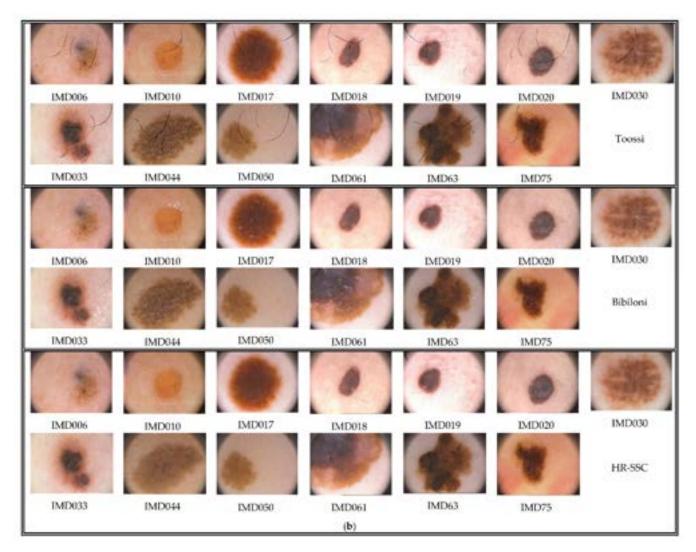


Figure 10. (a) Results of methods Lee, Xie, Abbas, Huang available in [37], rows 1–4, on H13GAN-data. (b) Results of methods Toossi, Figure 10. (a) Results of methods Lee, Xie, Abbas, Huang available in [37], rows 1–4, on H13GAN-data. (b) Results of Biblioni available in [37], rows 1–2, and results of HR-SSC, row 3, on H13GAN-data.
 Biblioni available in [37], rows 1–2, and results of HR-SSC, row 3, on H13GAN-data.

3.3: Quantitative Evaluation

We quantitatively evaluate the resulting images on the hairless image datasets to which hair has been added (see Section 3:1) by considering the original image as ground truth and expressing a quantitative evaluation in terms of the following:

- nine most popular quality measures: MSE, PSNR, MSE3, PSNR3, SSIM, MSSIM, VSNR, KIEPITOU AONOWSWR (40;41]; area of the detected hair regions;
- true/false discovery rate (see the definition in Section 3.3.3). true/false discovery rate (see the definition in Section 3.3.3).

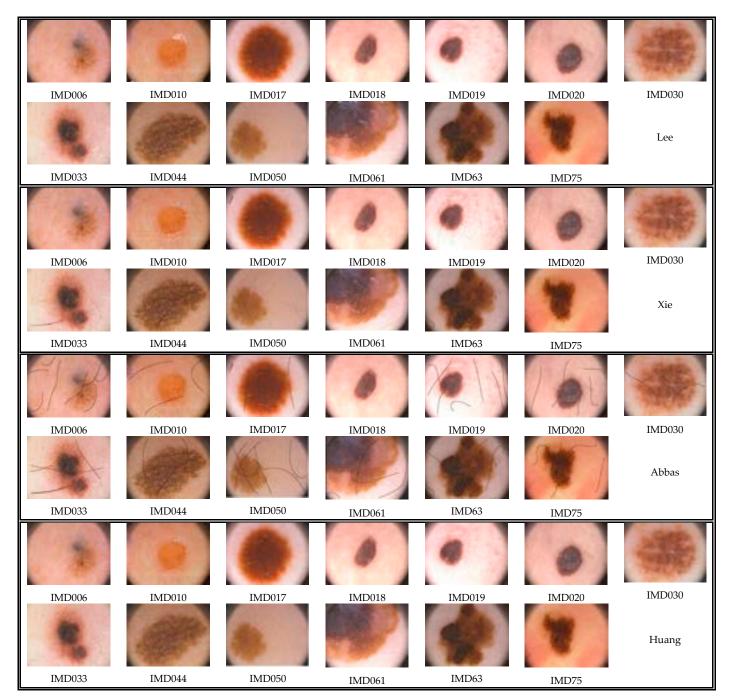
- "True/false dixXX+14 the Set the definition in Set 1 and 3.3.3. Although the above quality measures are related to human perception to a small extent, Although the above quality measures are related to human perception to a small extent, Although the above quality measures are related to human perception to a small extent, and the problem to define adequate metrics for the performance evaluation of color image fent, and the problem to define adequate metrics for the performance evaluation of color inage tent, and the problem to define adequate metrics for the performance evaluation of color processing methods remains an open problem widely studied [41–45], most often, measures are extensively employed to evaluate the performance of many types of analysis methods, including the HK methods [17,37]. In turn, we see these quality measure image analysis methods, including the HK methods [17,37]. In turn, we see these quality values as valid indicators since they contribute to delineate the trend of the performance of measure values as valid indicators since they contribute to delineate the trend of the performance of or its effectiveness. To overcome this gap, since the determination of the effective hair area and the true/false rate are the major critical points for the determination of the and the true false rate are the major critical points for the determination of HK effective hair area and the true/false rate are the major frite quantitative evaluation of HK effective hair area and the true/false rate are the performance evaluation by measuring the hair area and true/false and the grup false rate are the major critical points for the out of HK effective hair area and the true/false rate are the major critical points for the quantitative evaluation of HR methods, we extend the performance evaluation by measuring the hair area and thrue/false evaluation of HR methods. We extend the performance evaluation by measuring the hair area and thrue/false evaluation of HR methods of 3.3.2 and 3.3.5). As mentioned above

consider the images in which, in a controlled way, the hair regions are introduced on input hair-free images by using suitable hair insertion methods [38,39] that provide a hair-occluded image and the corresponding binary hair mask. The resulting binary mask is

Appl. Sci. 2021, 11, x FOR PEER REVIEWsed as ground truth to quantitatively evaluate the performance by computing the detected 13 of 27

area and the false discovery rate/true discovery rate (FDR/TDR). Note that we use the hairy images used in [17] and those available at [37]. Then,

we extend the controlled hair simulation on a larger dataset, and to allow comparison area and true/false rate (see respective Sections 3.3 2 and 3.3). As mentioned above, folwith other HR methods on the same image dataset, we made it available at the already lowing other Grinub fink. Inteed, currently, the direct comparison with the results shown are introducted papinnut hair free images the direct comparison with the results shown introducted papinnut hair free images the direct comparison with the results of the providens bairied ducted, image dingly the comparison ding heir argument of the first free images and the direct in a control with the results shown providens paintied ducted, image dingly the comparison ding heir argument of the methods (38, 39] that providens paintied ducted, image dingly the comparison ding heir argument of the paint of the source of the same dingly the the section of the source of the same dingly the the section of the same dingly the section of the same dingly the section of the section of the same dingly the section of the section of



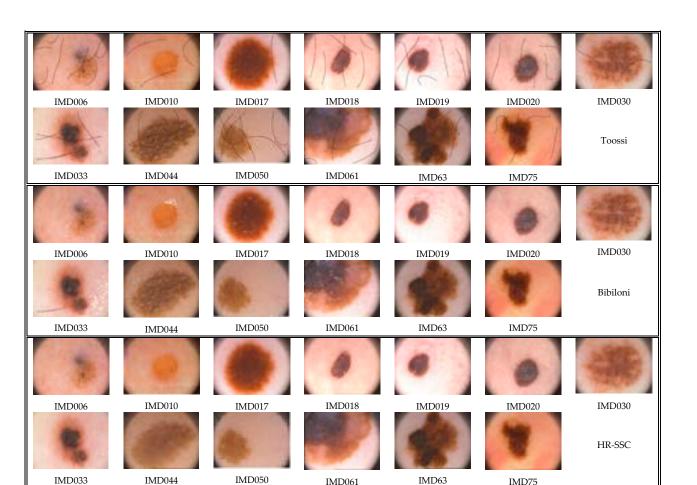


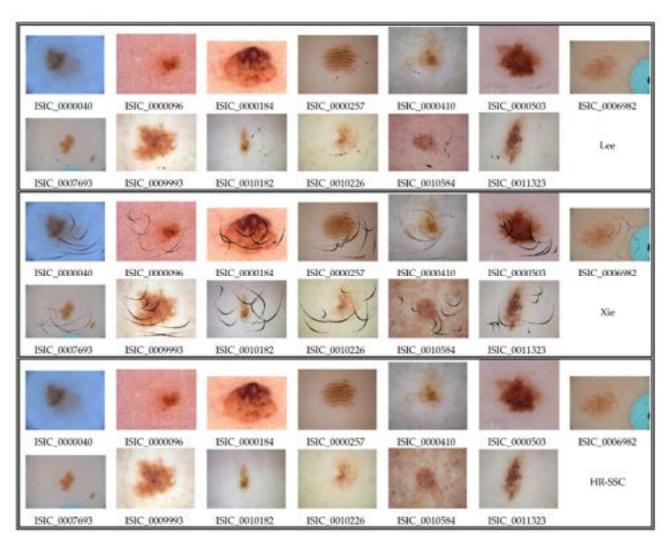
Figure 11. (APRESENTS (a) Resulta of the thods Autors, Finally as Analog an aliapte in [37] 47 on 41735 nn-4413.5 (b) Arts (b) Brinkth of mother, Bibiloni available in [37], rows 1–2, and results of HR-SSC, row 3, on H13Sim-data.

Note that we use the hairy images used in [17] and those available at [37]. Then, we 3.3.1. Quantitative Evaluation Based on Quality Measures extend the controlled hair simulation on a larger dataset, and to allow comparison with The arrive the notes of the index of the index of the controlled hair simulation on a larger dataset, and to allow comparison with The arrive the notes of the index of the index

insertion of the hairs and increasing the cardinality of the set of reference data, we obtain a similar result. This quality evaluation is performed by limiting the considered methods to Lee, Xie, and HR-SSC. For the sake of brevity, in Table 3, we show the metric values only for *sHSim-data* by considering the corresponding resulting images (see Figure 12) and the *sNH_data* (see Figure 7). In Table 4 we report the average quality measures referring to *H13GAN-data*, *H13Sim-data*, *sH13Sim-data*, and *HSim-data*. The quantitative metrics for the set *HSim-data* including 170 images are also available at the mentioned Github link since they require much editing space. SSC. For the sake of brevity, in Table 5, we show the resulting area values for *sHSim-data*. Moreover, we compare the average hair area $<A_1 >$ introduced in *HSim-data* by the Hair-Sim method with the average hair area detected by each method (Table 6).

Appl. Sci. 2021, 11, 447

Since in our experiment $<A_1 > = 42648$, from Table 6, it can be observed that the average hair area computed by HR-SSC is the one that comes closest to $<A_1 >$, while the average hair area computed by Xie is by far the most distant. This evaluation trend in terms of area on *HSim-data* and *sHSim-data* confirms the trend indicated in Section 3.3.1.



Higure 122 Results of methods Lee, Xie, and HR-SSC on sHSim-data.

Based on the quantitative analysis using the nine metrics, the trend of the various methods turns out to be completely different on *H13GAN-data* and *H13Sim-Data* in comparison with those on a set with greater cardinality *HSim-data* as well as on its sample *sHSim-data* of 13 images. This is highlighted in Figures 16 and 17, where the trends of each quality measure on the dataset containing 13 images belonging to different datasets but generated by the same HairSim method for the hair simulation, i.e., *H13Sim-data* and *sHSim-data*, are shown.

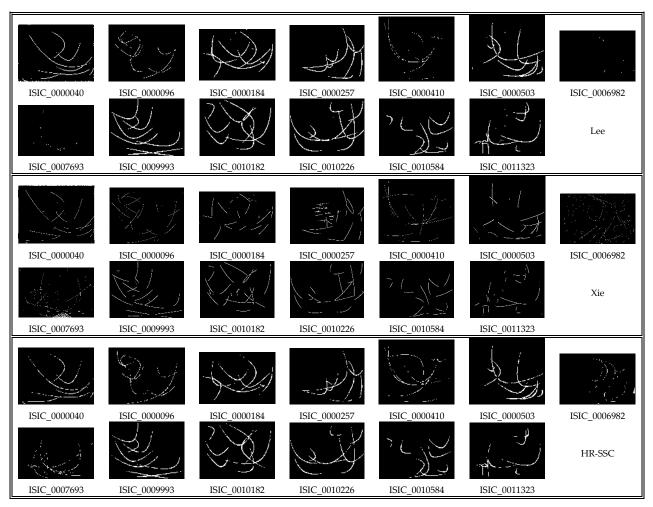


Figure 13: Resulting mask of HairSim method and the resulting mask of methods Lee, Xie, and HR-SSE on sHSim-data:

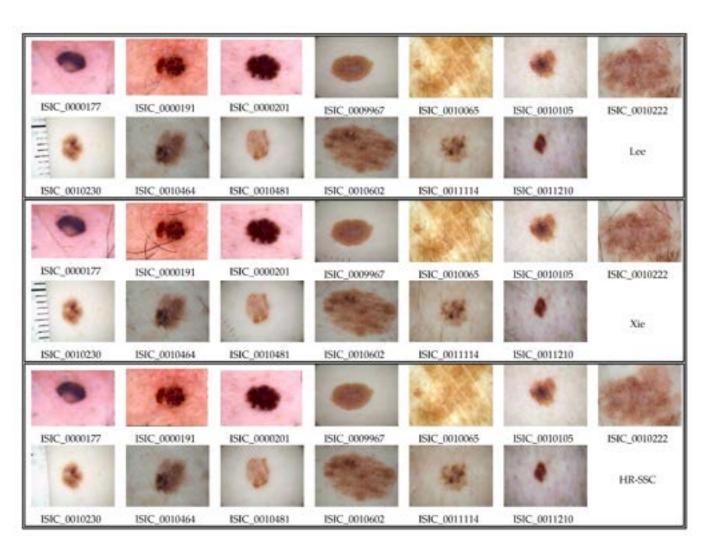


Figure 14. Results of methods Lee, Xie, and HR-SSC on sH-data.

3.3.3. Quantitative Evaluation in Terms of True/False Discovery Rate

We evaluate the quality of the resulting images also in terms of true discovery rate (TDR) and false discovery rate (FDR), defined as the following:

$$FDR = \frac{FP}{FP+TP}$$
 $TDR = 1 - FDR$

where FP and TP denote false positive and true positive assessments, respectively. For the sake of brevity, in Table 7, we show the resulting FDR and TDR values only for *sHSimdata*. Moreover, the average <FDR> and <TDR> values of each method for *HSimdata* are shown in Table 8. From the examination of Tables 7 and 8, a lower value of FDR and a higher value of TDR for HR-SSC, an intermediate value of FDR and TDR for Lee, and a higher value of FDR and a lower value of TDR for Xie can be observed. With respect to Lee, HR-SSC reports the percentage improvements of TDR and FDR equal to 35% and 27%, respectively, on *Hsimdata*, and equal to 33% and 27%, respectively, on *sHSimdata*. This evaluation trend in terms of FDR/TDR on *Hsimdata*, *sHSimdata* confirms the trend indicated in Section 3.3.1.

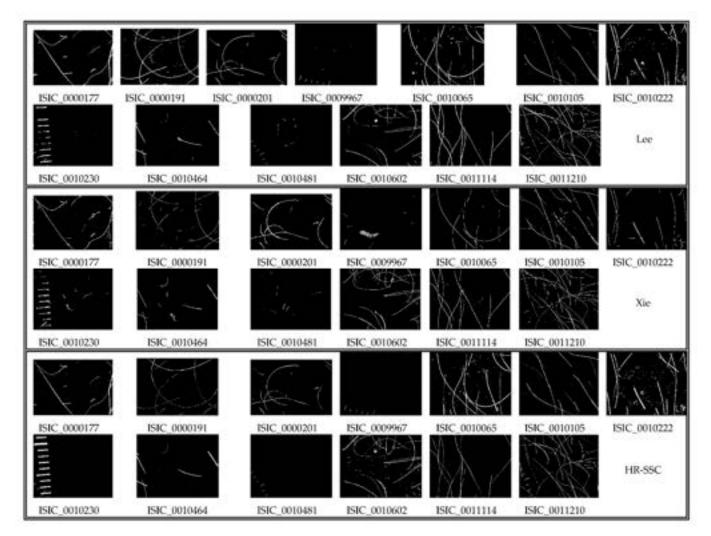


Figure 15. Resulting masks of methods Lee, Xie, and HR-SSC on sH-data.

13.626 12.610 57.555		20.918	34.926	0.888	10	AV 1-4				
	37.124			0.000	0.956	24.401	0.403	0.650	23.151	40.255
57 555		19.831	35.157	0.891	0.957	25.355	0.412	0.653	22.687	40.286
57.555	30.530	64.073	30.064	0.856	0.898	15.260	0.354	0.608	12.372	28.927
g 24.283	34.278	33.481	32.883	0.860	0.926	19.601	0.301	0.534	16.305	33.955
i 55.748	30.668	62.440	30.176	0.853	0.897	15.370	0.342	0.591	12.586	29.143
ni 19.653	35.197	28.070	33.648	0.867	0.943	21.588	0.328	0.589	19.411	36.740
C 19.669	35.193	27.078	33.805	0.861	0.941	21.101	0.323	0.561	20.950	37.581
44.373	31.660	52.734	30.910	0.855	0.939	16.990	0.352	0.659	18.189	33.261
46.305	31.475	55.898	30.657	0.859	0.931	15.853	0.364	0.665	14.288	30.576
88.070	28.683	98.376	28.202	0.838	0.907	14.944	0.330	0.636	14.129	28.725
g 42.985	31.798	52.674	30.915	0.818	0.905	17.330	0.236	0.510	17.169	32.186
i 90.161	28.581	100.956	28.089	0.832	0.905	15.007	0.320	0.618	13.841	28.495
ni 40.550	32.051	51.019	31.054	0.857	0.937	16.699	0.354	0.660	16.755	32.390
C 55.952	30.653	66.185	29.923	0.827	0.920	15.203	0.293	0.579	17.837	31.972
	1.00		V							
1222222	100	12222	111222	1.5	1121122	12222				
	si 55.748 ni 19.653 5C 19.669 44.373 46.305 ss 88.070 ig 42.985 si 90.161 ni 40.550 5C 55.952	si 55.748 30.668 ni 19.653 35.197 3C 19.669 35.193 44.373 31.660 46.305 31.475 ss 88.070 28.683 ug 42.985 31.798 si 90.161 28.581 ni 40.550 32.051 3C 55.952 30.653	si 55.748 30.668 62.440 nii 19.653 35.197 28.070 6C 19.669 35.193 27.078 44.373 31.660 52.734 46.305 31.475 55.898 ss 88.070 28.683 98.376 gg 42.985 31.798 52.674 si 90.161 28.581 100.956 nii 40.550 32.051 51.019 6C 55.952 30.653 66.185	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	si 55.748 30.668 62.440 30.176 0.853 0.897 15.370 0.342 0.591 mi 19.653 35.197 28.070 33.648 0.867 0.943 21.588 0.328 0.589 GC 19.669 35.193 27.078 33.805 0.861 0.941 21.101 0.323 0.561 44.373 31.660 52.734 30.910 0.855 0.939 16.990 0.352 0.659 46.305 31.475 55.898 30.657 0.859 0.931 15.853 0.364 0.665 ss 88.070 28.683 98.376 28.202 0.838 0.907 14.944 0.330 0.636 ig 42.985 31.798 52.674 30.915 0.818 0.905 17.330 0.236 0.510 si 90.161 28.581 100.956 28.089 0.832 0.905 15.007 0.320 0.618 mi 40.550 32.051 51.019 31.054 0.827 0.937 16.699 0.354 0.660	Si 55.748 30.668 62.440 30.176 0.853 0.897 15.370 0.342 0.591 12.586 mi 19.653 35.197 28.070 33.648 0.867 0.943 21.588 0.328 0.589 19.411 SC 19.669 35.193 27.078 33.805 0.861 0.941 21.101 0.323 0.561 20.950 44.373 31.660 52.734 30.910 0.855 0.939 16.990 0.352 0.659 18.189 46.305 31.475 55.898 30.657 0.859 0.931 15.853 0.364 0.665 14.288 ss 88.070 28.683 98.376 28.202 0.838 0.907 14.944 0.330 0.636 14.129 gg 42.985 31.798 52.674 30.915 0.818 0.905 17.330 0.236 0.510 17.169 si 90.161 28.581 100.956 28.089 0.832 0.905 15.007 0.320 0.618 13.841 mi 40.550 </td

Figure 16. Trends of quality measures on *H13Sim-data* for the methods Lee, Xie, and HR-SSC.

Img Met. MSE PSNR MSE3 PSNR3 SSIM MSSIM VSNR VIFP UQI NQM WSNR IMD017 Lee 18.625 35.430 24.645 34.213 0.881 0.955 20.130 0.445 0.711 27.399 98.837 Mung 29.318 33.499 25.611 32.615 0.884 0.955 30.411 0.455 0.711 23.473 32.835 Imag 29.318 33.499 37.67 33.247 0.887 0.937 25.118 0.356 0.662 17.373 28.516 IMD018 Lee 53.077 32.457 0.887 0.944 2.959 0.406 6.642 2.998 71.773 2.9571 0.845 0.971 0.334 0.578 23.688 40.335 0.581 0.827 0.578 23.688 40.335 0.581 1.818 2.863 35.015 1.416 3.77 3.448 3.930 0.861 0.957 2.413 0.574<	lable 1. Cont.												
Xie 16.228 30.028 20.70 34.53 0.854 0.955 30.41 0.455 0.714 25.465 Huang 29.318 33.459 35.451 32.615 0.854 0.907 21.18 0.060 17.73 25.555 Biblioni 24.312 34.273 0.874 0.846 0.907 25.158 0.040 0.662 7.230 35.660 IMD018 Lec 53.072 30.882 58.624 0.455 0.960 27.43 0.052 0.328 0.531 25.060 0.351 0.522 20.08 0.351 0.522 20.08 21.075 0.440 0.777 0.440 0.577 1.18 2.657 0.341 0.557 21.640 0.393 0.241 0.563 1.512 2.653 0.343 0.577 2.614 0.406 2.537 2.624 0.343 0.577 2.614 3.645 3.645 3.645 0.579 2.614 1.604 3.617 3.645 3.645 1.614	Img	Met.	MSE	PSNR	MSE3	PSNR3	SSIM	MSSIM	VSNR	VIFP	UQI	NQM	WSNR
Abbas 61.528 30.240 67.983 29.907 0.847 0.911 21.698 0.309 0.662 1.737 28.555 Huang 62.801 30.151 68.802 29.743 0.844 0.907 21.911 0.304 0.664 23.877 35.610 Biblioni 21.212 22.733 30.787 33.247 0.867 0.944 25.50 0.371 0.664 23.847 35.610 MD1018 Lee 53.072 30.852 58.624 39.957 0.865 0.960 27.331 0.315 0.564 29.586 40.348 Abbas 112.129 27.641 11.742 27.433 0.850 0.913 17.74 0.326 0.574 11.868 22.247 Intanag 65.664 29.87 11.42 0.852 0.913 17.74 0.340 0.574 12.18 2.86.89 Intonag 27.67 11.343 27.57 0.849 0.915 17.89 2.4135 0.417 0.	IMD017		18.625	35.430	24.645	34.213	0.881	0.957	29.130	0.445	0.711	27.359	38.837
Huang Doessi biblioni 29.318 (2.40) 33.459 (2.40) 32.615 (6.898) 0.854 (0.867) 0.937 (0.867) 21.511 (0.367) 0.366 (0.648) 0.446 (2.397) 22.682 (2.308) IMD018 Lee 53.072 30.882 58.624 0.450 0.850 0.934 2.635 0.331 0.581 22.039 55.006 MD018 Lee 53.072 30.882 58.624 0.450 0.865 0.996 2.7.33 0.352 0.578 2.3.68 0.353 MD018 Lee 53.072 30.875 71.73 2.5.71 0.846 0.939 2.2.471 0.366 0.466 1.5.89 3.2.222 Torossi 10.874 2.7.67 11.343 0.957 2.6.413 0.343 0.553 15.118 2.8.39 IMD019 Lee 40.674 32.038 4.999 3.1.142 0.882 0.942 2.4.15 0.414 0.667 1.2.02 3.5.377 IMD019 Lee 40.674 3.0.38 9.993 3.1.42		Xie	16.228	36.028	22.790	34.553	0.884	0.955	30.411	0.455	0.714	25.465	38.191
Biblioni C 2801 30.151 68.982 29.743 0.840 0.070 21.971 0.574 0.658 1.717 28.516 IHC-SC 31.007 33.216 30.787 33.247 0.867 0.948 25.50 0.371 0.652 23.808 34.512 IMD018 Lee 53.072 30.882 58.624 30.439 0.865 0.960 27.433 0.333 0.831 24.038 35.066 Abbas 112.129 27.634 117.432 27.433 0.850 0.913 17.475 0.344 0.554 15.181 28.474 Abbas 108.747 13.034 27.576 0.849 0.917 17.869 0.340 0.557 22.683 36.557 IMD019 Lee 41.459 31.402 0.836 0.937 24.135 0.417 0.706 14.20 0.837 0.417 0.706 31.343 0.565 14.366 0.377 0.677 16.018 32.315 0.565 0.566 <t< td=""><td></td><td>Abbas</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></t<>		Abbas											
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Abbas 112.122 27.634 117.432 27.433 0.850 0.913 17.475 0.344 0.570 14.966 28.474 Toossi 108.744 27.777 13.634 27.576 0.845 0.995 22.471 0.340 0.563 15.181 28.252 Biblioni 54.371 30.2761 39.240 32.194 0.853 0.955 24.135 0.327 0.537 22.68 0.475 IMD019 Lee 40.674 20.083 94.993 31.142 0.882 0.942 24.115 0.414 0.696 21.020 37.37 16.024 30.136 Toossi 81.0372 20.109 91.594 25.55 0.856 0.908 18.666 0.372 0.507 16.024 30.122 Biblioni 49.196 31.121 59.452 30.389 0.868 0.934 21.560 0.357 0.673 18.910 33.110 IMD020 Lee 54.462 30.770 61.126 30.269	IMD018												
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Abbas 80.579 29.069 90.699 28.555 0.856 0.904 18.686 0.372 0.657 16.024 30.163 Huang 60.703 30.299 71.582 29.583 0.827 0.904 20.229 0.235 0.657 18.011 32.313 Biblioni 49.196 31.212 59.452 30.389 0.868 0.934 23.136 0.355 0.672 19.580 34.043 IMD020 Lee 54.462 30.770 61.126 30.269 0.842 0.958 23.801 0.362 0.662 22.822 34.661 Xie 23.642 34.394 29.561 33.424 0.846 0.957 26.239 0.303 0.564 19.08 32.275 Toossi 125.759 27.135 132.244 26.907 0.796 0.841 16.111 0.295 0.581 14.456 27.197 Biblioni 59.850 30.260 67.565 30.522 0.823 0.951 22.181	IMD019												
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Abbas 132.080 26.922 138.996 26.701 0.803 0.883 15.764 0.306 0.604 14.074 26.834 Huang 62.554 30.168 69.851 29.689 0.815 0.936 21.317 0.303 0.564 19.108 32.275 Bibiloni 59.850 30.360 67.234 29.855 0.828 0.951 22.518 0.329 0.630 20.985 33.649 IMD030 Lee 50.827 31.070 57.665 30.522 0.869 0.959 26.493 0.413 0.669 18.341 32.247 Abbas 70.112 29.673 76.885 29.272 0.838 0.917 18.528 0.352 0.643 0.347 0.599 19.632 32.935 Toossi 72.517 29.526 79.211 29.143 0.830 0.912 18.530 0.337 0.609 19.599 19.632 32.935 Muang 50.526 79.211 29.143 0.830	IMD020		54.462	30.770	61.126	30.269	0.842		23.801	0.362	0.653	22.282	34.661
Huang Toossi62.55430.16869.85129.6890.8150.93621.3170.3030.56419.10832.275Biblioni59.8030.36067.23429.8570.7860.88416.1110.2950.58114.45627.197Biblioni59.8030.36067.23429.8570.8280.95122.6180.3290.50023.64136.222IMD030Lee50.82731.0757.66530.5220.8640.95219.9590.3980.66018.34132.244Abbas70.11229.67376.88529.2720.8830.91718.5280.3520.62315.44729.300Huang50.55631.09357.62030.5220.8470.94120.7430.3470.59919.63223.2935Toossi72.51729.52679.21129.1430.8300.91218.3300.3370.60015.61629.428Bibiloni45.92031.51153.06230.8830.8550.94921.6920.3720.64719.68033.360HR-SSC59.20230.40766.78329.8480.7860.94823.1460.3480.62320.94637.195MD033Lee20.7133.49636.22533.7070.8740.95426.2800.3920.57412.8128.385IMD034Lee20.75032.91040.51632.0550.8860.94821.6420.3020.5					29.561							25.905	
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Abbas70.11229.67376.88529.2720.8380.91718.5280.3520.62315.44729.300Huang50.55631.09357.62030.5250.8470.94120.7430.3470.59919.63232.935Toossi72.51729.52679.21129.1430.8300.91218.3300.3370.60015.61629.428Bibiloni45.92031.51153.06230.8830.8550.94921.6920.3720.64719.68033.360HR-SSC59.20230.40766.78329.8840.7860.90417.2040.2520.46819.00931.509IMD033Lee29.07133.49636.02832.660.8580.94823.1460.3480.62320.94637.195Xie20.68034.97527.69633.7070.8740.95426.2800.3890.64620.92838.139Abbas87.50528.71094.48928.3770.8250.89416.7620.3020.57412.08128.385Huang33.27032.91040.51632.0550.8360.92621.5840.2800.52318.37234.461Toossi86.21828.77593.27828.4330.8150.89016.7830.2660.54712.32428.584Bibiloni38.72232.25145.57731.5430.8370.96425.9710.4940.77423.18834.092	IMD030												
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Abbas72.92329.50278.28829.1940.8670.92616.2760.4570.75012.36925.924Huang105.87527.883110.17827.7100.7450.83512.9930.2100.48412.17423.933Toossi73.45229.47178.67429.1720.8590.92316.1100.4400.73612.44525.910Bibiloni96.72228.276101.89528.0490.7630.86713.7110.2420.56113.03024.693	IMD044												
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HR-5SC 176.341 25.667 179.590 25.588 0.673 0.734 11.356 0.143 0.345 9.157 20.718													
		HR-SSC	176.341	25.667	179.590	25.588	0.673	0.734	11.356	0.143	0.345	9.157	20.718

 Table 1. Cont.

Img	Met.	MSE	PSNR	MSE3	PSNR3	SSIM	MSSIM	VSNR	VIFP	UQI	NQM	WSNR
IMD050	Lee	35.787	32.594	41.721	31.927	0.880	0.954	18.895	0.335	0.578	17.676	31.938
	Xie	22.695	34.572	28.814	33.535	0.881	0.953	22.280	0.337	0.578	19.716	34.639
	Abbas	49.806	31.158	55.624	30.678	0.859	0.898	18.094	0.314	0.554	12.763	28.703
	Huang	22.682	34.574	29.144	33.485	0.852	0.932	22.328	0.232	0.453	18.434	34.242
	Toossi	49.658	31.171	55.452	30.692	0.856	0.897	18.151	0.300	0.536	12.899	28.805
	Bibiloni	24.683	34.207	30.624	33.270	0.876	0.949	20.898	0.335	0.575	19.338	33.924
	HR-SSC	32.032	33.075	38.428	32.284	0.863	0.944	21.815	0.269	0.507	19.705	34.589
IMD061	Lee	200.137	25.118	206.683	24.978	0.818	0.913	16.492	0.340	0.655	14.269	24.901
	Xie	31.045	33.211	39.240	32.194	0.853	0.947	28.493	0.401	0.701	24.189	35.438
	Abbas	162.905	26.011	170.740	25.807	0.774	0.862	19.898	0.262	0.585	17.621	27.216
	Huang	118.122	27.408	125.806	27.134	0.824	0.930	19.472	0.341	0.641	18.026	28.664
	Toossi	160.195	26.084	168.469	25.866	0.759	0.856	19.691	0.248	0.552	17.752	27.250
	Bibiloni	132.368	26.913	139.485	26.686	0.816	0.918	18.707	0.319	0.651	15.911	26.804
	HR-SSC	123.964	27.198	132.643	26.904	0.730	0.877	21.104	0.222	0.459	19.312	28.617
IMD063	Lee	73.087	29.492	78.056	29.207	0.868	0.949	16.458	0.395	0.638	18.376	27.193
	Xie	15.333	36.274	23.189	34.478	0.871	0.955	30.726	0.405	0.644	27.486	38.241
	Abbas	75.404	29.357	82.451	28.969	0.849	0.914	19.238	0.372	0.619	16.239	25.970
	Huang	82.506	28.966	87.606	28.705	0.846	0.931	15.781	0.328	0.563	16.786	25.992
	Toossi	74.619	29.402	81.598	29.014	0.847	0.914	19.316	0.364	0.608	16.268	25.989
	Bibiloni	74.387	29.416	80.223	29.088	0.861	0.948	16.314	0.374	0.626	18.402	27.149
	HR-SSC	38.011	32.332	44.806	31.617	0.852	0.945	25.076	0.355	0.586	21.399	30.795
IMD075	Lee	98.538	28.195	107.530	27.816	0.860	0.948	16.524	0.354	0.624	15.793	27.594
	Xie	18.342	35.496	29.230	33.473	0.866	0.952	26.945	0.373	0.635	24.586	38.198
	Abbas	73.194	29.486	82.107	28.987	0.845	0.926	18.078	0.336	0.606	16.732	28.717
	Huang	112.433	27.622	122.341	27.255	0.821	0.917	15.514	0.251	0.486	14.620	26.485
	Toossi	71.889	29.564	80.600	29.067	0.841	0.926	18.156	0.325	0.590	16.955	28.867
	Bibiloni	93.923	28.403	103.663	27.975	0.855	0.948	17.089	0.344	0.618	15.988	27.807
	HR-SSC	45.132	31.586	53.234	30.869	0.814	0.925	20.687	0.256	0.491	19.150	31.981

 Table 1. Cont.

Table 2. Quality evaluation of the results on the *H13Sim-data*—best results are in bold.

Img	Met.	MSE	PSNR	MSE3	PSNR3	SSIM	MSSIM	VSNR	VIFP	UQI	NQM	WSNR
IMD006	Lee	5.443	40.773	6.400	40.069	0.978	0.985	25.044	0.873	0.938	23.320	40.853
	Xie	6.105	40.274	8.712	38.730	0.998	0.971	22.402	0.898	0.944	18.362	36.300
	Abbas	146.175	26.482	149.923	26.372	0.920	0.836	9.709	0.747	0.877	6.777	23.447
	Huang	14.654	36.471	17.000	35.826	0.964	0.971	20.263	0.817	0.905	16.575	34.655
	Toossi	147.390	26.446	151.565	26.325	0.913	0.831	9.707	0.715	0.857	6.726	23.421
	Bibiloni	14.087	36.642	19.991	35.123	0.937	0.960	21.615	0.536	0.830	18.990	36.561
	HR-SSC	17.983	35.582	22.252	34.657	0.882	0.961	21.630	0.373	0.637	20.652	37.497
IMD010	Lee	44.462	31.651	45.490	31.552	0.960	0.969	15.108	0.844	0.935	14.718	30.440
	Xie	7.632	39.304	10.396	37.962	0.999	0.979	20.231	0.924	0.967	19.061	35.559
	Abbas	93.505	28.422	96.605	28.281	0.935	0.894	12.548	0.769	0.904	10.231	25.941
	Huang	21.230	34.861	22.192	34.669	0.962	0.967	20.111	0.819	0.919	17.995	33.880
	Toossi	94.868	28.360	99.195	28.166	0.926	0.889	12.520	0.734	0.882	10.253	25.956
	Bibiloni	49.427	31.191	55.047	30.723	0.973	0.971	16.917	0.850	0.953	14.449	30.158
	HR-SSC	54.625	30.757	61.890	30.215	0.856	0.937	15.234	0.353	0.666	17.575	31.736
IMD017	Lee	9.535	38.338	9.855	38.194	0.981	0.988	29.519	0.905	0.967	28.643	39.534
	Xie	11.082	37.684	16.277	36.015	0.997	0.986	27.386	0.955	0.979	21.083	32.729
	Abbas	64.666	30.024	67.694	29.825	0.941	0.934	20.432	0.758	0.902	15.536	26.897
	Huang	13.747	36.749	14.357	36.560	0.978	0.986	26.004	0.896	0.944	21.100	33.753
	Toossi	66.238	29.920	69.393	29.718	0.930	0.928	20.432	0.714	0.871	15.469	26.880
	Bibiloni	17.438	35.716	19.820	35.160	0.950	0.972	26.695	0.648	0.904	23.420	35.196
	HR-SSC	28.231	33.624	31.105	33.202	0.881	0.954	26.097	0.437	0.727	24.092	34.710

Ing Met. MSE PSNR MSE3 PSNR3 SSIM MSSIM VSNR VIFF UQI NQM WSNR IMD018 Lee 41.755 31.926 42.986 31.807 0.982 0.982 22.284 0.999 0.944 21.864 34.947 Abbas 43.683 31.738 44.480 31.610 0.972 0.983 22.286 0.921 21.782 34.447 Toossi 24.6405 24.221 251.071 24.132 0.936 22.226 0.792 0.903 21.232 34.447 IMD019 Lee 34.227 32.787 71.255 32.444 0.954 0.968 2.0690 0.770 0.908 21.011 36.83 86.37 32.173 36.411 31.935 0.986 0.399 21.011 0.863 0.837 0.757 0.921 32.217 36.611 36.33 8.22 22.517 31.341 0.945 0.946 21.851 36.35 8.627 22.517	Table 2. Cont.												
Xie 31.009 33.216 43.166 31.779 0.997 2.8252 0.825 0.9921 21.820 34.947 Huang 41.980 31.900 43.166 31.779 0.981 0.987 28.252 0.885 0.9921 21.822 34.447 Toossi 24.6405 24.212 251.091 24.132 0.983 0.792 0.983 27.266 0.872 0.9921 21.723 34.748 Biblioni 44.101 31.666 31.779 32.131 0.886 0.972 0.988 21.011 35.208 IMD019 Lcc 34.227 32.787 37.125 32.434 0.954 0.968 21.601 0.863 0.835 8.6.57 22.510 Nice 30.434 33.297 32.543 1.0467 0.954 0.968 0.790 0.857 0.632 32.101 35.208 1.221 34.31 0.942 1.937 32.101 35.208 1.221 34.31 0.942 1.937 32.101	Img	Met.	MSE	PSNR	MSE3	PSNR3	SSIM	MSSIM	VSNR	VIFP	UQI	NQM	WSNR
Abbas 43.883 31.78 44.880 31.610 0.972 0.983 27.268 0.829 0.922 1.21.782 34.445 Toossi 246.045 24.221 25.1091 24.132 0.936 0.831 11.292 0.841 0.911 4.242 23.138 Biblioni 44.101 31.66 45.644 31.337 0.972 0.983 27.256 0.792 0.930 21.352 34.448 IMD019 Lce 34.227 32.787 37.125 32.434 0.954 0.966 23.690 0.930 17.717 32.221 Huang 44.096 31.608 47.752 31.41 0.945 0.966 0.739 0.874 17.753 32.611 Toossi 31.4691 23.152 30.173 22.433 0.876 0.790 0.663 0.887 17.753 32.611 IMD20 Lce 50.227 0.310 92.019 0.966 2.1807 0.587 1.0735 2.2515 0.883 <t< td=""><td>IMD018</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></t<>	IMD018												
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Biblioni 44.101 31.686 45.648 31.537 0.972 0.983 27.202 0.792 0.930 21.523 34.748 IMD019 Lee 34.227 32.787 37.125 32.434 0.954 0.968 23.600 0.770 0.908 21.101 35.203 Mabbas 31.048 23.197 42.538 31.843 0.966 0.939 21.010 0.663 0.939 17.517 32.120 Toossi 31.6491 23.152 330.173 2.943 0.873 0.790 10.693 0.587 0.739 0.874 17.755 32.540 HR:SSC 46.419 31.464 94.858 31.188 0.897 0.960 22.956 0.454 0.754 22.614 1.843 32.597 IMD020 Lee 39.130 32.206 41.18 31.959 0.974 0.988 24.516 0.883 0.951 22.135 34.724 Abbas 151.33 22.051 11.502 24.574													
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Abbas 81.085 29.041 83.086 28.936 0.982 0.986 16.712 0.743 0.897 12.585 26.889 Huang 36.536 32.04 86.888 23.2468 0.982 0.986 21.820 0.911 0.960 20.087 33.643 Joossi 84.981 28.838 87.182 28.727 0.925 0.908 16.518 0.697 0.867 12.657 26.939 Bibiloni 36.763 32.477 39.569 32.157 0.954 0.971 21.777 0.675 0.913 19.905 33.500 IMD033 Lee 24.454 34.247 26.046 33.973 0.947 0.968 21.830 0.757 0.907 20.112 36.166 Abbas 189.799 25.348 194.689 25.237 0.901 0.855 12.471 0.662 0.853 6.665 23.295 Huang 18.819 35.385 19.675 35.192 0.956 0.966 22.401	IMD030	Lee	40.468	32.060	40.968	32.006	0.970	0.979	19.777	0.861	0.945	18.713	32.452
Huang Toossi 36.536 32.504 36.838 32.468 0.982 0.986 21.820 0.911 0.960 20.087 33.643 Bibiloni 36.763 32.477 39.569 32.157 0.925 0.908 16.518 0.697 0.867 12.657 26.939 Bibiloni 36.763 32.477 39.569 32.157 0.971 21.777 0.675 0.911 10.960 20.867 33.500 IMD033 Lee 24.454 34.247 26.046 33.973 0.947 0.968 21.830 0.757 0.907 20.112 36.196 Xie 22.402 34.628 31.323 33.172 0.995 0.958 20.109 0.915 0.952 13.498 30.916 Abbas 189.799 25.348 19.4689 25.237 0.901 0.852 12.471 0.662 0.823 7.391 23.295 Huang 18.819 35.385 19.675 35.192 0.956 0.966 22.401				41.810	6.163		0.998	0.987	26.467	0.927	0.969	23.432	37.889
Toossi 84.981 28.838 87.182 28.727 0.925 0.908 16.518 0.697 0.867 12.657 26.939 HR-SSC 63.601 30.096 68.802 29.755 0.782 0.901 16.937 0.245 0.462 17.583 30.554 IMD033 Lee 24.454 34.247 26.046 33.973 0.947 0.968 21.830 0.757 0.907 20.112 36.196 Xie 22.402 34.628 31.323 33.172 0.995 0.958 20.109 0.915 0.952 13.498 30.916 Abbas 189.799 25.348 194.689 25.237 0.901 0.855 12.471 0.662 0.853 6.665 23.295 Huang 18.819 35.385 19.675 35.192 0.956 0.966 22.401 0.823 7.391 23.923 Biblioni 69.269 29.725 73.560 29.464 0.902 19.19280 0.264 0.552		Abbas	81.085	29.041	83.086	28.936	0.938	0.915	16.712	0.743	0.897	12.585	26.889
Bibiloni HR-SSC 36.763 63.601 32.477 30.966 39.569 68.802 32.157 29.755 0.954 0.782 0.971 0.901 21.777 16.937 0.675 0.245 0.462 17.583 33.500 IMD033 Lee 24.454 34.247 26.046 33.973 0.947 0.968 21.830 0.757 0.907 20.112 36.196 Xie 22.402 34.628 31.323 33.172 0.995 0.958 20.109 0.915 0.952 13.498 30.916 Abbas 189.799 25.348 194.689 25.237 0.901 0.855 12.471 0.662 0.853 6.665 23.295 Huang 18.819 35.385 19.675 35.192 0.956 0.966 22.401 0.828 0.918 18.761 35.305 Toossi 169.486 25.839 174.635 25.709 0.890 0.852 12.952 0.624 0.823 7.391 23.923 Bibiloni 69.269 29.725 7.75.61 30.679 0.										0.911		20.087	
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Abbas 189.799 25.348 194.689 25.237 0.901 0.855 12.471 0.662 0.853 6.665 23.295 Huang 18.819 35.385 19.675 35.192 0.956 0.966 22.401 0.828 0.918 18.761 35.305 Toossi 169.486 25.839 174.635 25.709 0.890 0.852 12.952 0.624 0.823 7.391 23.923 Bibiloni 69.269 29.725 73.560 29.464 0.902 0.910 16.689 0.466 0.815 11.935 28.549 HR-SSC 50.811 31.071 55.613 30.679 0.816 0.921 19.280 0.264 0.552 17.666 33.302 IMD044 Lee 49.270 31.205 47.786 31.338 0.927 0.943 16.197 0.684 0.890 14.864 27.824 Abbas 39.651 32.148 39.209 32.197 0.955 0.945 7.650	IMD033			34.247	26.046				21.830	0.757		20.112	
Huang Toossi 18.819 35.385 19.675 35.192 0.956 0.966 22.401 0.828 0.918 18.761 35.305 Bibiloni 69.269 29.725 73.560 29.464 0.902 0.910 16.689 0.466 0.815 11.935 28.549 HR-SSC 50.811 31.071 55.613 30.679 0.816 0.921 19.280 0.264 0.552 17.666 33.302 IMD044 Lee 49.270 31.205 47.786 31.338 0.927 0.943 16.197 0.684 0.890 14.864 27.824 Xie 7.508 39.376 10.183 38.052 0.998 0.980 23.052 0.924 0.973 18.344 32.600 Abbas 39.651 32.148 39.209 32.197 0.955 0.945 17.653 0.790 0.934 13.447 27.292 Toossi 44.653 31.632 44.317 31.665 0.941 0.938 17.253		Xie	22.402	34.628	31.323	33.172	0.995	0.958	20.109	0.915	0.952	13.498	
Toossi169.48625.839174.63525.7090.8900.85212.9520.6240.8237.39123.923Bibiloni69.26929.72573.56029.4640.9020.91016.6890.4660.81511.93528.549HR-SSC50.81131.07155.61330.6790.8160.92119.2800.2640.55217.66633.302IMD044Lee49.27031.20547.78631.3380.9270.94316.1970.6840.89014.86427.824Xie7.50839.37610.18338.0520.9980.98023.0520.9240.97318.34432.600Abbas39.65132.14839.20932.1970.9550.94517.6530.7900.93413.44727.293Huang73.35429.47771.51029.5870.8910.90114.1200.5940.81312.37225.252Toossi44.65331.63244.31731.6650.9410.93817.2530.7340.91113.25026.963Bibiloni124.03427.195127.43927.0780.7640.82912.4160.2210.56211.71922.787HR-SSC214.18324.823214.14724.8240.6710.71810.4980.1420.3428.44519.567IMD050Lee21.35534.83621.80734.7450.9760.98420.0820.8600.93019.013 </td <td></td> <td>Abbas</td> <td></td> <td></td> <td>194.689</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td>		Abbas			194.689								
Bibiloni HR-SSC 69.269 50.811 29.725 31.071 73.560 55.613 29.464 30.679 0.902 0.816 0.901 0.921 16.689 19.280 0.466 0.264 0.815 0.552 11.935 17.666 28.549 33.302 IMD044 Lee 49.270 31.205 47.786 31.338 0.927 0.943 16.197 0.684 0.890 14.864 27.824 Xie 7.508 39.376 10.183 38.052 0.998 0.980 23.052 0.924 0.973 18.344 32.600 Abbas 39.651 32.148 39.209 32.197 0.955 0.945 17.653 0.790 0.934 13.447 27.293 Huang 73.354 29.477 71.510 29.587 0.891 0.901 14.120 0.594 0.813 12.372 25.252 Toossi 44.653 31.632 44.317 31.665 0.941 0.938 17.253 0.734 0.911 13.250 26.963 Bibiloni 124.034 27.195 127.439 27.078 </td <td></td>													
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Abbas 39.651 32.148 39.209 32.197 0.955 0.945 17.653 0.790 0.934 13.447 27.293 Huang 73.354 29.477 71.510 29.587 0.891 0.901 14.120 0.594 0.813 12.372 25.252 Toossi 44.653 31.632 44.317 31.665 0.941 0.938 17.253 0.734 0.911 13.250 26.963 Bibiloni 124.034 27.195 127.439 27.078 0.764 0.829 12.416 0.221 0.562 11.719 22.787 HR-SSC 214.183 24.823 214.147 24.824 0.671 0.718 10.498 0.142 0.342 8.445 19.567 IMD050 Lee 21.355 34.836 21.807 34.745 0.976 0.984 20.082 0.860 0.930 19.013 33.138 Xie 5.561 40.680 7.855 39.179 0.998 0.970 25.606	IMD044		49.270	31.205	47.786	31.338		0.943	16.197	0.684	0.890	14.864	27.824
Huang Toossi 73.354 29.477 71.510 29.587 0.891 0.901 14.120 0.594 0.813 12.372 25.252 Toossi 44.653 31.632 44.317 31.665 0.941 0.938 17.253 0.734 0.911 13.250 26.963 Bibiloni 124.034 27.195 127.439 27.078 0.764 0.829 12.416 0.221 0.562 11.719 22.787 HR-SSC 214.183 24.823 214.147 24.824 0.671 0.718 10.498 0.142 0.342 8.445 19.567 IMD050 Lee 21.355 34.836 21.807 34.745 0.976 0.984 20.082 0.860 0.930 19.013 33.138 Xie 5.561 40.680 7.855 39.179 0.998 0.970 25.606 0.874 0.934 19.433 36.204 Abbas 121.210 27.295 122.357 27.255 0.930 0.838 <td< td=""><td></td><td>Xie</td><td>7.508</td><td>39.376</td><td>10.183</td><td>38.052</td><td>0.998</td><td>0.980</td><td>23.052</td><td>0.924</td><td>0.973</td><td>18.344</td><td></td></td<>		Xie	7.508	39.376	10.183	38.052	0.998	0.980	23.052	0.924	0.973	18.344	
Toossi 44.653 31.632 44.317 31.665 0.941 0.938 17.253 0.734 0.911 13.250 26.963 Bibiloni 124.034 27.195 127.439 27.078 0.764 0.829 12.416 0.221 0.562 11.719 22.787 HR-SSC 214.183 24.823 214.147 24.824 0.671 0.718 10.498 0.142 0.342 8.445 19.567 IMD050 Lee 21.355 34.836 21.807 34.745 0.976 0.984 20.082 0.860 0.930 19.013 33.138 Xie 5.561 40.680 7.855 39.179 0.998 0.970 25.606 0.874 0.934 19.433 36.204 Abbas 121.210 27.295 122.357 27.255 0.930 0.838 12.242 0.790 0.895 7.594 23.528 Huang 10.580 37.886 11.262 37.615 0.965 0.979 23.658<			39.651	32.148	39.209			0.945	17.653	0.790	0.934	13.447	
Bibiloni 124.034 27.195 127.439 27.078 0.764 0.829 12.416 0.221 0.562 11.719 22.787 HR-SSC 214.183 24.823 214.147 24.824 0.671 0.718 10.498 0.142 0.342 8.445 19.567 IMD050 Lee 21.355 34.836 21.807 34.745 0.976 0.984 20.082 0.860 0.930 19.013 33.138 Xie 5.561 40.680 7.855 39.179 0.998 0.970 25.606 0.874 0.934 19.433 36.204 Abbas 121.210 27.295 122.357 27.255 0.930 0.838 12.242 0.790 0.895 7.594 23.528 Huang 10.580 37.886 11.262 37.615 0.965 0.979 23.658 0.821 0.915 19.415 35.929 Toossi 120.022 27.338 121.174 27.297 0.927 0.837 <		Huang											
HR-SSC 214.183 24.823 214.147 24.824 0.671 0.718 10.498 0.142 0.342 8.445 19.567 IMD050 Lee 21.355 34.836 21.807 34.745 0.976 0.984 20.082 0.860 0.930 19.013 33.138 Xie 5.561 40.680 7.855 39.179 0.998 0.970 25.606 0.874 0.934 19.433 36.204 Abbas 121.210 27.295 122.357 27.255 0.930 0.838 12.242 0.790 0.895 7.594 23.528 Huang 10.580 37.886 11.262 37.615 0.965 0.979 23.658 0.821 0.915 19.415 35.929 Toossi 120.022 27.338 121.174 27.297 0.927 0.837 12.359 0.769 0.886 7.647 23.580 Bibiloni 37.044 32.444 40.803 32.024 0.969 0.971													
IMD050 Lee 21.355 34.836 21.807 34.745 0.976 0.984 20.082 0.860 0.930 19.013 33.138 Xie 5.561 40.680 7.855 39.179 0.998 0.970 25.606 0.874 0.934 19.433 36.204 Abbas 121.210 27.295 122.357 27.255 0.930 0.838 12.242 0.790 0.895 7.594 23.528 Huang 10.580 37.886 11.262 37.615 0.965 0.979 23.658 0.821 0.915 19.415 35.929 Toossi 120.022 27.338 121.174 27.297 0.927 0.837 12.359 0.769 0.886 7.647 23.580 Bibiloni 37.044 32.444 40.803 32.024 0.969 0.971 18.740 0.817 0.920 16.150 30.032			124.034						12.416			11.719	
Xie5.56140.6807.85539.1790.9980.97025.6060.8740.93419.43336.204Abbas121.21027.295122.35727.2550.9300.83812.2420.7900.8957.59423.528Huang10.58037.88611.26237.6150.9650.97923.6580.8210.91519.41535.929Toossi120.02227.338121.17427.2970.9270.83712.3590.7690.8867.64723.580Bibiloni37.04432.44440.80332.0240.9690.97118.7400.8170.92016.15030.032		HR-SSC	214.183	24.823	214.147	24.824	0.671	0.718	10.498	0.142	0.342	8.445	19.567
Xie5.56140.6807.85539.1790.9980.97025.6060.8740.93419.43336.204Abbas121.21027.295122.35727.2550.9300.83812.2420.7900.8957.59423.528Huang10.58037.88611.26237.6150.9650.97923.6580.8210.91519.41535.929Toossi120.02227.338121.17427.2970.9270.83712.3590.7690.8867.64723.580Bibiloni37.04432.44440.80332.0240.9690.97118.7400.8170.92016.15030.032	IMD050	Lee	21.355	34.836	21.807	34.745	0.976	0.984	20.082	0.860	0.930	19.013	33.138
Abbas121.21027.295122.35727.2550.9300.83812.2420.7900.8957.59423.528Huang10.58037.88611.26237.6150.965 0.979 23.6580.8210.91519.41535.929Toossi120.02227.338121.17427.2970.9270.83712.3590.7690.8867.64723.580Bibiloni37.04432.44440.80332.0240.9690.97118.7400.8170.92016.15030.032					7.855			0.970					36.204
Huang10.58037.88611.26237.6150.9650.97923.6580.8210.91519.41535.929Toossi120.02227.338121.17427.2970.9270.83712.3590.7690.8867.64723.580Bibiloni37.04432.44440.80332.0240.9690.97118.7400.8170.92016.15030.032													
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Bibiloni 37.044 32.444 40.803 32.024 0.969 0.971 18.740 0.817 0.920 16.150 30.032		0					0.927	0.837	12.359	0.769	0.886		23.580
			37.044		40.803	32.024	0.969		18.740	0.817	0.920	16.150	
		HR-SSC	28.878	33.525	32.355	33.031	0.893	0.964	22.466	0.344	0.632	20.099	34.948

Table 2. Cont.

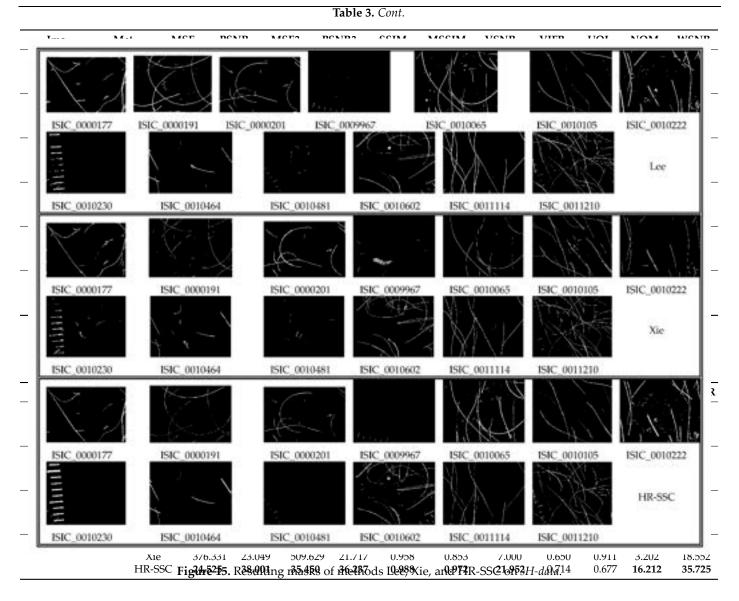
Img	Met.	MSE	PSNR	MSE3	PSNR3	SSIM	MSSIM	VSNR	VIFP	UQI	NQM	WSNR
IMD061	Lee	199.214	25.138	197.816	25.168	0.918	0.934	15.841	0.705	0.881	14.097	24.753
	Xie	13.371	36.869	18.984	35.347	0.994	0.973	25.671	0.915	0.962	21.197	32.801
	Abbas	231.503	24.485	238.370	24.358	0.869	0.848	17.243	0.568	0.811	12.035	22.788
	Huang	92.491	28.470	92.932	28.449	0.965	0.979	19.645	0.871	0.939	17.979	28.910
	Toossi	230.406	24.506	237.676	24.371	0.853	0.839	17.117	0.526	0.778	11.960	22.729
	Bibiloni	125.200	27.155	127.409	27.079	0.919	0.937	18.203	0.551	0.875	15.407	26.464
	HR-SSC	120.609	27.317	126.001	27.127	0.760	0.895	21.122	0.254	0.535	19.579	28.808
IMD063	Lee	62.239	30.190	60.750	30.295	0.984	0.977	16.040	0.902	0.959	18.381	27.253
	Xie	6.407	40.064	9.620	38.299	0.996	0.982	27.252	0.931	0.968	22.772	33.216
	Abbas	88.233	28.674	89.376	28.619	0.961	0.937	15.611	0.820	0.927	14.729	24.462
	Huang	67.139	29.861	65.432	29.973	0.975	0.975	15.731	0.871	0.937	16.992	26.398
	Toossi	94.791	28.363	95.625	28.325	0.954	0.934	15.164	0.784	0.909	14.397	24.068
	Bibiloni	63.394	30.110	63.387	30.111	0.972	0.977	16.033	0.778	0.937	18.206	27.103
	HR-SSC	37.731	32.364	41.061	31.997	0.880	0.963	25.120	0.395	0.671	20.784	30.350
IMD075	Lee	84.834	28.845	86.173	28.777	0.979	0.983	16.386	0.880	0.951	15.894	27.734
	Xie	4.125	41.977	5.986	40.359	0.999	0.986	27.081	0.932	0.969	23.102	37.372
	Abbas	123.562	27.212	123.997	27.197	0.951	0.917	14.234	0.803	0.920	11.946	24.537
	Huang	92.738	28.458	93.963	28.401	0.970	0.977	15.607	0.851	0.934	14.744	26.916
	Toossi	131.867	26.929	132.950	26.894	0.942	0.913	13.898	0.762	0.897	11.703	24.251
	Bibiloni	77.560	29.234	79.014	29.154	0.976	0.982	16.953	0.825	0.949	16.059	28.034
	HR-SSC	42.993	31.797	46.676	31.440	0.829	0.944	21.012	0.286	0.539	19.158	32.117
-												

Table 2. Cont.

Table 3. Quality evaluation of the results on the *sHSim-data*—best results are in bold.

Img	Met.	MSE	PSNR	MSE3	PSNR3	SSIM	MSSIM	VSNR	VIFP	UQI	NQM	WSNR
ISIC_0000040	Lee	284.167	23.595	378.463	22.351	0.976	0.952	8.877	0.712	0.916	0.702	19.995
	Xie	184.397	25.473	295.277	23.429	0.977	0.874	3.327	0.562	0.923	2.318	19.575
	HR-SSC	114.313	27.550	158.448	26.132	0.982	0.985	8.688	0.697	0.611	15.389	31.447
ISIC_0000096	Lee	8.604	38.784	13.237	36.913	0.997	0.983	16.692	0.905	0.956	14.830	36.493
	Xie	164.330	25.974	236.750	24.388	0.985	0.917	3.736	0.818	0.950	2.842	21.224
	HR-SSC	5.160	41.005	12.589	37.131	0.996	0.961	20.198	0.716	0.614	16.606	39.021
ISIC_0000184	Lee	26.720	33.862	39.355	32.181	0.995	0.959	20.266	0.815	0.915	16.444	31.995
	Xie	391.069	22.208	580.441	20.493	0.966	0.848	9.115	0.711	0.903	4.434	17.907
	HR-SSC	12.844	37.044	19.339	35.267	0.995	0.966	24.759	0.728	0.801	19.208	34.899
ISIC_0000257	Lee	14.885	36.403	20.021	35.116	0.993	0.974	14.336	0.750	0.922	10.323	32.190
	Xie	244.908	24.241	326.325	22.994	0.966	0.854	1.574	0.528	0.911	1.219	17.999
	HR-SSC	1.094	47.739	1.910	45.320	0.998	0.994	31.166	0.845	0.652	23.113	46.466
ISIC_0000410	Lee	11.893	37.378	16.306	36.007	0.989	0.986	14.863	0.831	0.957	12.455	33.225
	Xie	138.029	26.731	186.638	25.421	0.975	0.923	3.274	0.690	0.953	3.516	21.231
	HR-SSC	2.346	44.427	4.869	41.257	0.971	0.976	22.008	0.620	0.354	20.210	41.823
ISIC_0010503	Lee	14.655	36.471	21.322	34.843	0.987	0.970	18.175	0.771	0.923	15.295	33.283
	Xie	209.160	24.926	297.527	23.396	0.961	0.877	5.627	0.644	0.913	3.655	19.156
	HR-SSC	3.716	42.430	5.489	40.736	0.992	0.987	27.291	0.673	0.646	21.392	39.927
ISIC_0006982	Lee	4.379	41.717	6.318	40.125	0.997	0.991	17.597	0.896	0.968	17.799	39.600
	Xie	78.818	29.165	106.018	27.877	0.990	0.950	3.448	0.840	0.957	4.028	23.575
	HR-SSC	15.341	36.272	23.827	34.360	0.990	0.947	10.670	0.479	0.342	8.234	32.009

Appl. Sci. 2021, 11, x FOR PEER REVIEW



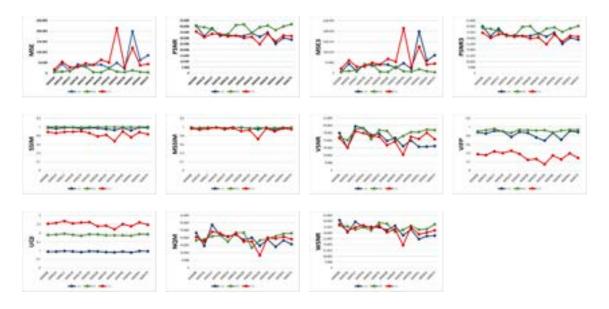


Figure 16. Trends of quality measures on H13Sim-data for the methods Lee, Xie, and HR-SSC.

23 of 27

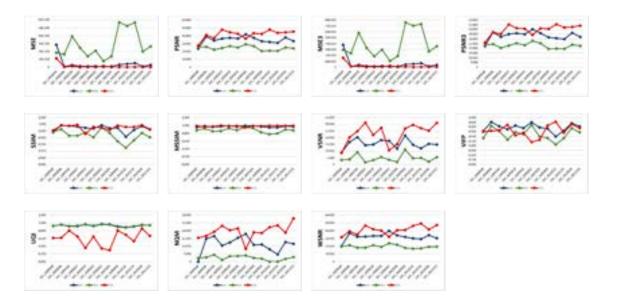


Figure 17: Frends of quality measures on sHSim-data for the methods Lee; Xie; and HR-SSE:

Table 5. Hair area on sHSim-data—best results are in bold 3.3.2. Quantitative Evaluation Based on the Area of the Detected Hair Regions

				ve ev a luation ba			the areawalues
		obtainelsity the					
		hair is astreeding			,	, , .	,
		introduged byothe		. ,	, 0	, ,	,
		area idestified by	en meth	od, indigated as	AB,446, AR, re	spectively	for Leos Xie, and
		HR-SSGSFor thes	ake of brevit	y, in Table 5, we s	how the resulti	ug area yalu	es for sHSimodata.
		Moreover, we can	pare the ave	erage hair area <	Abz introduced	in HSim-da	ta by the HairSim
		method with the ISIC_0006	average hair	area detected by	y each method	Table 6).	106,147
		ISIC 0007 Table 5. Hair area of				5,984,212	135,523
		ISIC 0009	on <i>sHSim-aata</i> 993	-best results are 1 35,991	n bold. 47,248	766,116	38,432
		I61£ _0010	182 A _I	36,257 A _L	44,818	A7,64,856	38 ,127
		ISIC 1500004010	226 47,608	33,226 77,00	0141,208 1,6	6 5,791 008	5 4,9,85 77
		ISIC_1910009010			2027,634 3,1	06,040687	7 <u>8,1</u> ,9892
		ISIC-1990018411	323 32,827	20,309 42,11		³ 774,768	³ 22,641
		ISIC_0000257	<u>26,069</u> 86 122			8,308 41 140	28,057
		ISIC_0000410 Table Average ha	air area yalue	s on the HSim ₃ dat	20 4,5 22to compare wit	$h_{4,917}^{41,149} = 420$	105,109 548—best results 28,063
		are is 10006982	73,066			10,208	106,147
		ISIC_0007693 Datase	et 100,975		ζΔ.,	84,212	135,523 38 432
		ISIC 00109993		(1.045		6,116 36856	<u></u>
		ISIC_001010226	33,226			0,008	34,677
Table	e 7. False disco	veryISAGe_(FCDR5)84nd				,	
	Mat	ISIC_0011323	20,309 TDD	_ , ,o.		4,768	<u>22,041</u>
Img	Met.		TDR	Img	Met.	FDR	TDR
ISIC_0000040	Lee	Table 6. Average ha		on the HSim-data		< A1 >= 426	48—best results are
	Xie	in bold?80	0.020		Xie	0.992	0.008
	HR-SSC	0.202	0.798		HR-SSC	0.469	0.531
ISIC_0000096	Lee	0.3 Bataset	0.697	ISf@ <u></u> 20009993	Lee <a<sub>x></a<sub>	0.641	<a<sub>R(?:359</a<sub>
	Xie	0. 985 m-data	0.015	61,045	X 1e 594,363	0.992	48,830008
	HR-SSC	0.206	0.794		HR-SSC	0.456	0.544
ISIC_0000184	Lee	0.293	0.707	ISIC_0010182	Lee	0.631	0.369

3.3.3. Quantitative Evaluation in Terms of True/False Discovery Rate

We evaluate the quality of the resulting images also in terms of true discovery rate (TDR) and false discovery rate (FDR), defined as the following:

$$FDR = \frac{FP}{FP + TP}$$
 $TDR = 1 - FDR$

where FP and TP denote false positive and true positive assessments, respectively. For the sake of brevity, in Table 7, we show the resulting FDR and TDR values only for *sHSim-data*. Moreover, the average <FDR> and <TDR> values of each method for *HSim-data* are shown in Table 8. From the examination of Tables 7 and 8, a lower value of FDR and a higher value of TDR for HR-SSC, an intermediate value of FDR and TDR for Lee, and a higher value of FDR and a lower value of TDR for Xie can be observed. With respect to Lee, HR-SSC reports the percentage improvements of TDR and FDR equal to 35% and 27%, respectively, on *Hsim-data*, and equal to 33% and 27%, respectively, on *sHSim-data*. This evaluation trend in terms of FDR/TDR on *Hsim-data*, *sHSim-data* confirms the trend indicated in Section 3.3.1.

Table 7. False discovery rate (FDR) and true discovery rate (TDR) on sHSim-data—best results are in bold.

Img	Met.	FDR	TDR	Img	Met.	FDR	TDR
ISIC_0000040	Lee	0.326	0.674	ISIC_0007693	Lee	0.651	0.349
	Xie	0.980	0.020		Xie	0.992	0.008
	HR-SSC	0.202	0.798		HR-SSC	0.469	0.531
ISIC_0000096	Lee	0.303	0.697	ISIC_0009993	Lee	0.641	0.359
	Xie	0.985	0.015		Xie	0.992	0.008
	HR-SSC	0.206	0.794		HR-SSC	0.456	0.544
ISIC_0000184	Lee	0.293	0.707	ISIC_0010182	Lee	0.631	0.369
	Xie	0.988	0.012		Xie	0.992	0.008
	HR-SSC	0.217	0.783		HR-SSC	0.444	0.556

Table 7. Cont.

Img	Met.	FDR	TDR	Img	Met.	FDR	TDR
ISIC_0000257	Lee	0.311	0.689	ISIC_0010226	Lee	0.628	0.372
	Xie	0.987	0.013		Xie	0.992	0.008
	HR-SSC	0.211	0.789		HR-SSC	0.439	0.561
ISIC_0000410	Lee	0.299	0.701	ISIC_0010584	Lee	0.618	0.382
	Xie	0.989	0.011		Xie	0.992	0.008
	HR-SSC	0.243	0.757		HR-SSC	0.427	0.573
ISIC_0000503	Lee	0.281	0.719	ISIC_0011323	Lee	0.608	0.392
	Xie	0.991	0.009		Xie	0.992	0.008
	HR-SSC	0.276	0.724		HR-SSC	0.416	0.584
ISIC_0006982	Lee	0.654	0.346				
	Xie	0.992	0.008				
	HR-SSC	0.464	0.536				

	<fdr></fdr>	<tdr></tdr>
Lee	0.503	0.497
Xie	0.990	0.010
HR-SSC	0.360	0.640

 Table 8. Average FDR and TDR on the HSim-data—best results are in bold.

4. Discussion and Conclusions

In this paper, we propose the method HR-SSC based on the combined use of saliency, shape, and color. Initially, the computation burden of the hair removal process is lowered optionally by reducing the size of the image. Then, pseudo-hair regions and border/corner components are determined and employed in the successive process of hair mask detection. Successively, the image is restored by an inpainting process. A further contribution of this paper includes the proposal of a method for qualitative and quantitative evaluation of an HR method, and the availability of appropriate datasets to be used for testing and comparing by others. According to the proposed evaluation method, we perform a detailed quantitative and qualitative analysis of the experimental results on these datasets. Specifically, we qualitatively evaluate the performance of the proposed method and six state-of-the-art methods. We quantitatively evaluate the performance of HR methods under examination using a hair simulation technique applied on available dermoscopic image datasets, nine commonly adopted quality measures, area criteria, and FDR/TDR indicators.

Based on the experimental results and the performance evaluation, HR-SSC detects and removes the hair from the dermoscopic image by preserving the image features for its subsequent image segmentation process. Moreover, HR-SSC has a competitive and satisfactory performance concerning other considered methods as the probability of missing hair regions and/or detecting false hair regions is low. This is visually evident from the evaluation carried out, but it is to a lesser extent if we restrict the analysis to *NH13-data*. Indeed, as also reported in [17], the quantitative results on *H13GAN-data* and *H13Sim-data* (see Tables 1 and 2) indicate that the method Xie statistically outperforms the other methods under consideration, including HR-SSC. However, this experimental evidence does not match the qualitative/quantitative results obtained on the larger dataset *HSim-data* and on its sample, which, on the contrary, indicate a better performance of the proposed method. This trend is validated also by the qualitative evaluation based on area and TDR/FDR as reported respectively in Sections 3.3.2 and 3.3.3.

In summary, according to the performance evaluation, HR-SSC achieves good qualitative and quantitative results with an adequate balance. Moreover, it detects hair regions rapidly by processes with limited complexity. The results have also demonstrated the effectiveness and the utility of the employment of saliency, shape, and color information for hair removal problems. Finally, the implementation does not require any extensive learning based on a high number of parameters and labeled training images, and its execution time is quite fast.

In future investigations, there is room to extend the comparative studies with other existing methods and to improve this work by applying more efficient and efficacy inpainting methods to increase the performance quality.

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References

- 1. Okur, E.; Turkan, M. A survey on automated melanoma detection. Eng. Appl. Artif. Intell. 2018, 73, 50–67. [CrossRef]
- 2. Oliveira, R.B.; Papa, J.P.; Pereira, A.S.; Tavares, J.M.R.S. Computational methods for pigmented skin lesion classification in images: Review and future trends. *Neural Comput. Appl.* **2018**, *29*, 613–636. [CrossRef]
- Masood, A.; Jumaily, A.A. A Computer Aided Diagnostic Support System for Skin Cancer: A Review of Techniques and Algorithms. *Int. J. Biom. Imag.* 2013. [CrossRef] [PubMed]
- Vocaturo, E.; Zumpano, E.; Veltri, P. Image pre-processing in computer vision systems for melanoma detection. In Proceedings of the 2018 IEEE International Conference on Bioinformatics and Biomedicine (BIBM), Madrid, Spain, 6 December 2018; pp. 2117–2124.
- Kavitha, N.; Vayelapelli, M. A Study on Pre-Processing Techniques for Automated Skin Cancer Detection. Smart Technologies in Data Science and Communication; Fiaidhi, J., Bhattacharyya, D., Rao, N., Eds.; Lecture Notes in Networks and Systems; Springer: Berlin/Heidelberg, Germany, 2020; Volume 105, pp. 145–153.
- Michailovich, O.V.; Tannenbaum, A. Despeckling of medical ultrasound images. *IEEE Trans. Ultras. Ferroelect. Freq. Control* 2006, 53, 64–78. [CrossRef] [PubMed]
- 7. Ramella, G.; Sanniti di Baja, G. A new technique for color quantization based on histogram analysis and clustering. *Int. J. Patt. Recog. Art. Intell.* **2013**, 27, 13600069. [CrossRef]
- Bruni, V.; Ramella, G.; Vitulano, D. Automatic Perceptual Color Quantization of Dermoscopic Images. In VISAPP 2015; Scitepress Science and Technology Publications: Setúbal, Portugal, 2015; Volume 1, pp. 323–330.
- 9. Ramella, G.; Sanniti di Baja, G. A new method for color quantization. In Proceedings of the 12th International Conference on Signal Image Technology & Internet-Based Systems—SITIS 2016, Naples, Italy, 28 November–1 December 2016; pp. 1–6.
- Bruni, V.; Ramella, G.; Vitulano, D. Perceptual-Based Color Quantization. Image Analysis and Processing—ICIAP 2017; Lecture Notes in Computer Science 10484; Springer: Berlin/Heidelberg, Germany, 2017; pp. 671–681.
- Premaladha, J.; Lakshmi Priya, M.; Sujitha, S.; Ravichandran, K.S. A Survey on Color Image Segmentation Techniques for Melanoma Diagnosis. *Indian J. Sci. Technol.* 2015, 8, IPL0265.
- 12. Ramella, G.; Sanniti di Baja, G. *Image Segmentation Based on Representative Colors and Region Merging in Pattern Recognition;* Lecture Notes in Computer Science 7914; Springer: Berlin/Heidelberg, Germany, 2013; pp. 175–184.
- Ramella, G.; Sanniti di Baja, G. From color quantization to image segmentation. In Proceedings of the 2016 12th International Conference on Signal-Image Technology & Internet-Based Systems (SITIS), Naples, Italy, 28 November–1 December 2016; IEEE: Piscataway Township, NJ, USA, 2016; pp. 798–804.
- Ramella, G. Automatic Skin Lesion Segmentation based on Saliency and Color. In VISAPP 2020; Scitepress Science and Technology Publications: Setúbal, Portugal, 2020; Volume 4, pp. 452–459.
- 15. Ramella, G. Saliency-based segmentation of dermoscopic images using color information. arXiv 2020, arXiv:2011.13179.
- Celebi, M.E.; Wen, Q.; Iyatomi, H.; Shimizu, K.; Zhou, H.; Schaefer, G. A state-of-the-art survey on lesion border detection in dermoscopy images. In *Dermoscopy Image Analysis*; Celebi, M.E., Mendonca, T., Marques, J.S., Eds.; CRC Press: Boca Raton, FL, USA, 2016; pp. 97–129.
- Talavera-Martinez, L.; Bibiloni, P.; Gonzalez-Hidalgo, M. Comparative Study of Dermoscopic Hair Removal Methods. In Proceedings of the ECCOMAS Thematic Conference on Computational Vision and Medical Image Processing, Porto, Portugal, 16–18 October 2019; Springer: Berlin/Heidelberg, Germany, 2019.
- 18. Lee, T.; Ng, V.; Gallagher, R.; Coldman, A.; McLean, D. Dullrazor: A software approach to hair removal from images. *Comput. Biol. Med.* **1997**, *27*, 533–543. [CrossRef]
- 19. Xie, F.-Y.; Qin, S.-Y.; Jiang, Z.-G.; Meng, R.-S. PDE-based unsupervised repair of hair-occluded information in dermoscopy images of melanoma. *Comput. Med. Imaging Graph.* **2009**, *33*, 275–282. [CrossRef]
- Abbas, Q.; Celebi, M.E.; Fondón García, I. Hair removal methods: A comparative study for dermoscopy images. *Biomed. Signal Process. Control.* 2011, 6, 395–404. [CrossRef]
- Huang, A.; Kwan, S.-Y.; Chang, W.-Y.; Liu, M.-Y.; Chi, M.-H.; Chen, G.-S. A robust hair segmentation and removal approach for clinical images of skin lesions. In Proceedings of the 35th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBS), Osaka, Japan, 3–7 July 2013; pp. 3315–3318.
- 22. Toossi MT, B.; Pourreza, H.R.; Zare, H.; Sigari, M.H.; Layegh, P.; Azimi, A. An effective hair removal algorithm for dermoscopy images. *Skin Res. Technol.* **2013**, *19*, 230–235. [CrossRef] [PubMed]
- 23. Bibiloni, P.; Gonzàlez-Hidalgo, M.; Massanet, S. Skin Hair Removal in Dermoscopic Images Using Soft Color Morphology. In *AIME 2017*; Lecture Notes in Artificial Intelligence 10259; Springer: Berlin/Heidelberg, Germany, 2017; pp. 322–326.
- Koehoorn, J.; Sobiecki, A.; Rauber, P.; Jalba, A.; Telea, A. Efficient and Effective Automated Digital Hair Removal from Dermoscopy Images. *Math. Morphol. Theory Appl.* 2016, 1, 1–17.
- 25. Zaqout, I.S. An efficient block-based algorithm for hair removal in dermoscopic images. *Comput. Optics.* 2017, 41, 521–527. [CrossRef]
- 26. Attia, M.; Hossny, M.; Zhou, H.; Nahavandi, S.; Asadi, H.; Yazdabadi, A. Digital hair segmentation using hybrid convolutional and recurrent neural networks architecture. *Comput. Methods Programs Biomed.* **2019**, *177*, 17–30. [CrossRef] [PubMed]
- 27. Talavera-Martinez, L.; Bibiloni, P.; Gonzalez-Hidalgo, M. An Encoder-Decoder CNN for Hair Removal in Dermoscopic Images. *arXiv* 2020, arXiv:2010.05013v1.

- Mendonca, T.; Ferreira, P.M.; Marques, J.S.; Marcal, A.R.; Rozeira, J. PH²–A public database for the analysis of dermoscopic images. In *Dermoscopy Image Analysis*; Celebi, M.E., Mendonca, T., Marques, J.S., Eds.; CRC Press: Boca Raton, FL, USA, 2015; pp. 419–439.
- 29. ISIC 2016. ISIC Archive: The International Skin Imaging Collaboration: Melanoma Project, ISIC. Available online: https://isic-archive.com/# (accessed on 5 January 2016).
- Itti, L.; Koch, C.; Niebur, E. A model of saliency-based visual attention for rapid scene analysis. *IEEE Trans. Patt. Anal. Mach. Intell.* 1998, 20, 1254–1259. [CrossRef]
- 31. Haralick, R.; Sternberg, S.R.; Huang, X. Image Analysis Using Mathematical Morphology. IEEE Trans. PAMI 1987, 4, 532–550. [CrossRef]
- 32. Soille, P. Morphological Image Analysis: Principles and Applications; Springer: Berlin/Heidelberg, Germany, 2004.
- 33. Serra, J.; Vincent, L. An Overview of Morphological Filtering. Circuits Systems Signal Process. 1992, 11, 47–108. [CrossRef]
- 34. Guarracino, M.R.; Maddalena, L. SDI+: A Novel Algorithm for Segmenting Dermoscopic Images. *IEEE J. Biomed. Health Inf.* 2019, 23, 481–488. [CrossRef]
- Otsu, N. A Threshold Selection Method from Gray-Level Histograms. *IEEE Trans. Systems Man Cybern.* 1979, *9*, 62–66. [CrossRef]
 Achanta, R.; Hemami, S.; Estrada, F.; Susstrunk, S. Frequency-tuned salient region detection. In Proceedings of the 2009 IEEE Conference on Computer Vision and Pattern Recognition, Miami, FL, USA, 20–25 June 2009; IEEE: Piscataway Township, NJ, USA, 2009; pp. 1597–1604.
- 37. Dermaweb. Available online: http://dermaweb.uib.es/ (accessed on 26 November 2020).
- 38. Attia, M.; Hossny, M.; Zhou, H.; Yazdabadi, A.; Asadi, H.; Nahavandi, S. Realistic Hair Simulator for Skin lesion Images Using Conditional Generative Adversarial Network. *Preprints* **2018**, 2018100756. [CrossRef]
- 39. HairSim by Hengameh Mirzaalian. Available online: http://creativecommons.org/licenses/by-nc-sa/3.0/deed.en_US (accessed on 26 November 2020).
- Mitsa, T.; Varkur, K.L. Evaluation of contrast sensitivity functions for the formulation of quality measures incorporated in halftoning algorithms. In Proceedings of the IEEE International Conference on Acoustics, Speech, and Signal Processing (ICASSP), Minneapolis, MN, USA, 27–30 April 1993; pp. 301–304.
- 41. Ramella, G. Evaluation of quality measures for color quantization. arXiv 2020, arXiv:2011.12652.
- 42. Chandler, D.M. Seven Challenges in Image Quality Assessment: Past, Present, and Future Research. *ISRN Signal Process.* 2013, 2013, 1–53. [CrossRef]
- 43. Lee, D.; Plataniotis, K.N. Towards a Full-Reference Quality Assessment for Color Images Using Directional Statistics. *IEEE Trans. Image Process.* **2015**, *24*, 3950–3965. [CrossRef] [PubMed]
- 44. Lin, W.; Kuo, C.-C.J. Perceptual visual quality metrics: A survey. J. Vis. Commun. Image Represent. 2011, 22, 297–312. [CrossRef]
- 45. Liu, M.; Gu, K.; Zhai, G.; Le Callet, P.; Zhang, W. Perceptual Reduced-Reference Visual Quality Assessment for Contrast Alteration. *IEEE Trans. Broadcast.* **2016**, *63*, 71–81. [CrossRef]