Facial Photo Blending System By Using Digital Image Processing

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ABSTRACT: This paper introduces a new Photo Blending system approach to FSS in pursuit of performance enhancement regarding verification and recognition identity, which current approaches typically fail to realize when it tends to miss some important specific identity information in the traditional approach. Inter-domain transfer occurs without losing any critical facial structures that are learnt as regressor between test and training photos; and intra-domain transfer tries to boost recovery of identity-specific information through a mapping of relationships between sketches and photographs across different identities. To facilitate research in this area, we present FS2K, a comprehensive dataset containing 2,104 image-sketch pairs that encompass various sketch styles, backgrounds, and facial attributes. Additionally, we propose FSGAN, a baseline method that utilizes facial-aware masking and style- vector expansion, significantly outperforming existing state-of-the art models on the FS2K dataset. Our dual Path Frame- work With its finest adjustment of coarse crossdomain reconstructed texture into a finer resolution and then combined with detailed refinement, in addition to a spatial feature calibration module that boosts alignment, the proposed method supports exemplar-guided image-to-image translation and fine-grained crossdomain editing tasks. Thorough experiments demonstrate that the aforementioned method is better in both photo-to- sketch synthesis and identification recognition tasks; consequently, our framework contributes valuable insights as well as resources to the FSS research community.

Keywords: Face Sketch Synthesis (FSS), Inter-domain Transfer, FS2K Dataset, FSGAN, Dual Path Framework.

I. INTRODUCTION

This is another research area in computer vision that has gained more importance with its applications in digital forensics, entertainment, and virtual reality. In particular, in terms of blending facial features from sketches and photographs, inherent differences in the representation between these modalities pose challenges. This paper discusses a dual transfer framework which combines both deep learning architectures and traditional image manipulation techniques in order to achieve high-quality facial photo blending.

For evaluating our proposed framework's performance, we rely on a mix of quantitative and qualitative measures. We assess Peak Signal-to-Noise Ratio (PSNR), Structural Similarity Index Measure (SSIM) and Fre´chet Inception Distance (FID) scores, which together allow for a holistic evaluation of the images generated at output. Besides them, we also do user studies to take ratings from subjects about the realisms and art qualities of the generated images.

Our model begins from intra-domain transfer, which clearly shows the gaps between face structures in an image and a sketch. Although the linear models are very effective for this task, they fail in practice because the interactions of these modalities are very complex. In this respect, we apply a nonlinear GAN-based model, as it is much friendlier with the complex relationship contained within facial features.

We design a heuristic information splitting and fusion strategy that differentiate common facial information from identity-specific details. In such a way, the two-strategy approach can efficiently benefit from inter-domain transfer by source images with common facial structures, and deal with intra-domain transfer where high-frequency images are rich in identity-specific information.

Despite all these improvements, our framework is still exposed to problems in style variation, consistency in identity, and real-time processing capability. We qualitatively analyze our proposed framework and show its capabilities to produce high-quality facial images with contextual plausibility on both modalities. Through various experiments, we validate the effectiveness of our approach towards generating images from sketches to photographs and highly realistic sketches from photographs.

All of these challenges will be overcome, and this work will contribute to the development of digital forensics, virtual reality, and entertainment with a robust solution to facial photo blending, and form the basis for further development in this vibrant field.

II. RELATED WORK

a. Image Embedding in the Latent Space of StyleGAN: Abdal, Qin, and Wonka (2019) brought forth the technique of image embedding into the latent space of StyleGAN, which was one of the crucial techniques. The embedding of images into the latent space of the StyleGAN makes it feasible to control attributes in the latent space, which in turn breaks the barriers in the style transfer as well as realistic image synthesis [1].

b. Generative Latent Bank for Super-Resolution of Images: Chan, Wang, Xu, Gu, and Loy developed GLEAN, a high-quality large-factor generative latent bank-based image super-resolution enhancement model effective in high- resolution outputs on low-resolution images [2].

c. Face Photo Recognition by Using Sketches: The use of sketches for the cross-domain image processing on recognizing face photos was the work of Tang and Wang way back in 2002 [3].

d. Face Sketch Synthesis via n E-HMM and Selective Ensemble: In the proposal offered by Zhong, Li, Tian, and Gao in 2008, the synthesis of a face sketch using an n E- HMM with selective ensemble enhances the accuracy in creating face sketches [4].

e. Superpixel-Based Face Sketch–Photo Synthesis: Peng, Gao, Wang, and Li enhanced the photo-sketch synthesis method by using the superpixel-based approach towards preserving most of the local detail features existing in face sketches [5].

f. Semi-Coupled Dictionary Learning for Super-Resolution and Photo-Sketch Synthesis: Wang, Zhang, Liang, and Pan in 2012 used semi-coupled dictionary learning. The approach is known to be effective for the usage of applications like super-resolution and photo-sketch synthesis [6].

g. 3D Object Representation for Fine-Grained Categorization: In 2013, Krause, Stark, Deng, and Li had concentrated on the representations of objects in three- dimensional space that have increased fine-grained categorization in aiding the tasks related to object recognition [7].

h. Neural Representation of Sketch Drawings: Ha and Eck have presented a model of the neural network representing drawings of a sketch allowing better comprehension of the machine regarding hand-drawn images [8].

i. Texture Networks for Feed forward Synthesis of Textures and Stylized Images: Ulyanov et al. (2016) introduced texture networks. They enable the production of textures and stylised images much more efficiently compared to earlier methods involving an iterative procedure [9].

j. Deep Convolutional Networks for Inverse Problems in Imaging: Jin, McCann, Froustey, and Unser (2017) applied deep convolutional networks to solve challenging inverse problems in imaging to demonstrate the power of deep learning for complicated image processing operations [10]. k.Face Photo Recognition Using Sketch (Recurrent): Tang and Wang’s face photo recognition using sketches technique, a recurrent element in the list, constitutes the underlying technology in this domain of the research [11].

l.Locally Linear Embedding for Nonlinear Dimensionality Reduction: Roweis and Saul were the scientists who proposed applying locally linear embedding to face images with a high dimension toward nonlinear dimensionality reduction [12].

m.Robust Face Sketch Style Synthesis: Zhang, Gao, Wang, and Li (2016) proposed a robust technique to face sketch synthesis with respect to different sketching styles to attempt to tackle the problem of stylized image translation [13].

n.Convolutional Neural Networks for Image Style Recognition: Sun, Wang, Yang, and Hu in 2017 proposed the convolutional neural networks with dual pathways to amplify the difference between the style for image recognition processing [14].

o. Generative Adversarial Networks: Goodfellow et al. introduced the core framework called GANs, since then developing realistic image synthesis and styles manipulation [15].

p. Face Sketch-Photo Synthesis Using Sparse Representation: Gao, Wang, Tao, and Li proposed the sketch- photo synthesis technique based on sparse representation within a multi-dictionary framework that enhanced photo- sketch synthesis and retrieval tasks [16].

q. Style Transfer Using Texture Synthesis: Elad and Milanfar published an approach for texture synthesis that enabled flexibility in the style transformation applied to images[17].

r.U-GAT-IT: Unsupervised Generative Attentional Network for Image Translation: Kim, Kim, Kang, and Lee authored this unsupervised framework of the year 2020. U-GAT-IT is developed with the combination of attention and adaptive normalization to make it effectively useful for image-to-image translation where applications comprise sketch synthesis or style transfer [18].

s.Face Sketch-Photo Synthesis Using Multi-Dictionary Sparse Representation: In the year 2011, Wang, Gao, Tao, and Li adopted the sketch-photo synthesis with the help of a multi-dictionary sparse representation method for achieving translation precisely from the sketch into the photo [19].

t.Deep Convolutional Network for Image Super-Resolution: In the year 2014, Dong, Loy, He, and Tang discussed deep convolutional networks, whereby image resolution enhancement may only open more horizons toward more perfect methods for the image super-resolution technique [20].

III. METHODOLOGIES

The dual-branch GAN framework proposed architecture is based on the following components:
a. Dual-Branch Generators: G1 for sketch-to-photo, and G2 for photo-to-sketch transformations.
b. Adversarial Training: G and D are trained adversarially, enhancing the quality of output images.
c. Cycle-Consistency Mechanism: It helps ensure the identi- ties of the images in round-trip conversions.
The methodology allows the system to learn adaptively complex mappings between sketch and photo domains, thus improving the overall quality of synthesis.
i. Model Evaluation: Model evaluation tests the performance of the trained GAN models under various criteria:
ii. Quality Assurance: The quality assurance is ensured through strict validation techniques so that images generated meet requirements.Several architectures were comparatively compared for the best model configuration for both tasks.
iii. Fine-Tuning: Hyperparameter fine-tuning was carried out by adjusting the parameters of learning rates, batch sizes, and loss weights to optimize performance.
iv. Business Decision Support: The synthesized images can be utilized for applications in law enforcement-for example, forensic sketching-and digital art, helping in quick decision- making processes.
v. Model Deployment: The final model is deployed in a user- friendly interface where end-users can input sketches or photos and receive the corresponding transformations in real time.
vi. Constraints: The proposed system stands promising, but a number of constraints need to be kept in mind: Authenticity in the outputted images is essential, especially when the application requires real-world representation, such as in law enforcement agencies.
vii. Privacy: Facial data is a privacy issue and thus requires regulation and proper ethical approach.
viii. Cost: GAN models are computationally expensive to train. They require high-performance GPUs and significant amounts of energy. The quality of the input data determines the performance of the model; hence, it's crucial to have quality datasets.
ix. Availability of Resources: Availability of rich computational resources and large amounts of data is inconvenient but necessary in resource-constrained environments.

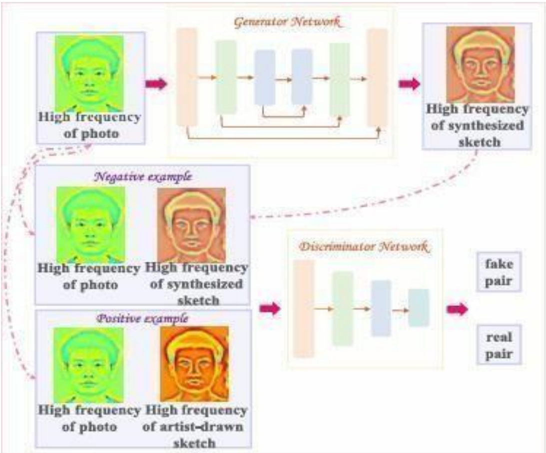

Fig. 1. Model Evaluation Framework

The Fig 1 shows a GAN model where the Generator creates a high-frequency synthesized sketch from a photo, and the Discriminator evaluates whether the sketch is real (artist- drawn) or fake (synthesized). The discriminator compares the sketch against either a positive (real) or negative (fake) example to classify it.

a. Model Training using DeepFaceLab: DeepFaceLab uses a combination of autoencoders and

GANs to perform face blending. The model architecture consists of two autoencoders (AE1 and AE2): one for the input face and another for the target face. These autoencoders are trained to compress and reconstruct the faces in latent space, and later they perform blending in this space. The system employs the following steps:

i. Dual Autoencoder Training:

- Train two autoencoders (AE1 for photo-to-sketch blend- ing).Each autoencoder learns to map faces into a latent feature space, where facial attributes (texture, expression, shape) are encoded.

ii. Latent Space Blending:

- Extract the encoded representations from both faces and blend them by interpolating their latent vectors. This blending is controlled by setting different blending ratios to create a smooth transition between facial identities.

b. System Architecture

The proposed system shall be based on the dual-branch GAN architecture where both the generators and the discriminators would work in tandem to perform both sketch-to-photo and photo-to-sketch synthesis. It shall comprise of the following:

a. Generator G1: Converts sketches into photorealistic images and learns the mapping between the sketch domain and photo domain. item

b. Generator G2: Learn inverse mapping from photo-space to sketch-space in order to transform photos to sketches. item

c. Discriminator D1: To judge real and generated images as photorealistic or not as long as the synthesized images are photorealistic. item

d. Discriminator D2: To distinguish between real and generated sketches so that the generated sketches visually coherent with the original sketching style.

All of these components are trained adversarially: The generators are trained to evade the discriminators, while the discriminators are trained to accurately separate real and generated images. Additionally, to ensure photo-to-sketch, while preserving important features of input images, a cycle- consistency loss is incorporated.

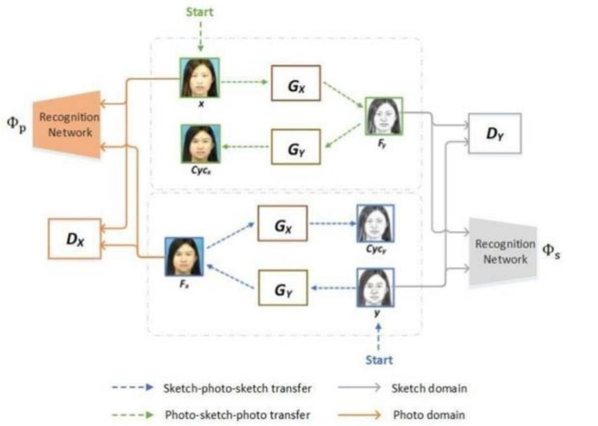

Fig. 2. Analysis of Constraints in the Proposed System

The Fig 2 shows a dual-domain system where generators GX and GY convert photos to sketches and sketches back to photos, ensuring cycle consistency. Discriminators evaluate the conversions, and recognition networks validate the authenticity of the transformations in both the sketch and photo domains.

c. Training Pipeline

The following is for the training of alternating photo-to-sketch tasks while minimizing both adversarial and reconstruction losses. For the system, the publicly available dataset also includes the following:

i. CUFS Dataset: It's a face sketch dataset that people ex- tensively use; it allows sketch and photo pairs from various individuals to be used in sketch-to-photo and photo-to-sketch synthesis tasks.

ii. CelebA Dataset: It is a very large-scale facial image dataset consisting of many different facial features, poses, and light- ing. This enhances the generalization capability of the model when dealing with actual photographs.

The proposed system makes use of multiple loss functions for synthesis in both directions to create high-quality synthesis in Adversarial Loss

The adversarial loss for both generators is defined as follows:

$$L_{adv}(G, D) = Ex \sim \text{data}\,[\log D(x)] + Ez \sim p(z)\,[\log(1 - D(G(z)))] \quad (1)$$

where (G) is the generator,
(D) is the discriminator,
(x) is the real image
(z) is the noise vector.

d. Cycle-Consistency Loss: The cycle-consistency loss is defined as:

$$L_{cyc}(G_1, G_2) = Ex \sim \text{data}\,[\| G_2(G_1(x)) - x \|_1] + Ey \sim \text{data}\,[\| G_1(G_2(y)) - y \|_1] \quad (2)$$

where G1 and G2 are generators for the corresponding tasks.

Reconstruction Loss The reconstruction loss minimizes the pixel-wise difference:

$$\mathcal{L}_{rec}(G) = \mathbb{E}_{x\sim data} \|x - G(x)\|_2^2 \quad (3)$$

Perceptual Loss The perceptual loss captures high-level features from pre-trained networks:

$$\mathcal{L}_{percept}(G) = \sum_{l\in L} \|\phi_l(x) - \phi_l(G(x))\|_2^2 \quad (4)$$

where ϕl is feature extraction at layer l of a pre-trained network.

Combining these losses with an overall loss function helps steer the training:

$$\mathcal{L}_{total} = \lambda_{adv}\mathcal{L}_{adv} + \lambda_{cyc}\mathcal{L}_{cyc} + \lambda_{rec}\mathcal{L}_{rec} + \lambda_{percept}\mathcal{L}_{percept} \quad (5)$$

Where λ are hyperparameters that balance the contributions of each loss.

e. Performance Evaluation: To evaluate the performance of the proposed system, both qualitative and quantitative metrics are used:

1. Peak Signal-to-Noise Ratio (PSNR): Measures the overall image quality between the generated image and the ground truth. Structural Similarity Index (SSIM) Structures Simulates consistency with the reference image.

2. Frechet Inception Distance (FID): Determines the quality of images produced by comparing the feature distributions of generated and real images.

3. Identity Preservation Metric: This metric would guarantee that the synthesized image (both the sketch and photo) is preserving the identity of the original image; very important for applications such as forensic sketching.

Here the Fig 3 shows how to plot a plots loss over

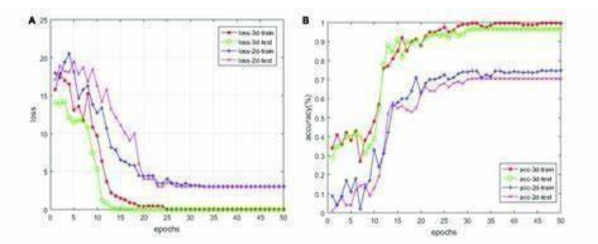

Fig. 3. Training Loss Curves for Adversarial and Cycle-Consistency Loss

training epochs for both configurations a few of these decay to a minimum point others decay without reaching a minimum point-those indicate models are also learning plot b plots accuracy or another performance metric against iteration and it shows general trend but shows that some of the other models settle at higher levels than others these then plot lines demonstrating how comparatively the models are effective-that is to say how fast and efficiently they learn and improve at every step of the training process.

f. Implementation Details

The proposed system is implemented using the Python programming language along with the deep learning framework PyTorch. With respect to processing, the training is done on GPUs. The architecture is trained end-to- end by incorporating adversarial, cycle-consistency, and reconstruction losses.

IV. EXPERIMENTED RESULTS AND DISCUSSION

To present the result and discussion detail regarding a facial photo blending system especially by using the datasets such as CUFS, CUHK Face Sketch Database, and GAN models, you can follow this detailing of the experiment along with the framework of the discussion while analyzing the system below.

a.Qualitative Quality: The composite image captures the identity of the subject but is both a photograph and a sketch. Good level of facial details, the eyes, nose, and the lips blend so convincingly, and the textures of the sketches carry over so remarkably well to the photographs of the face.

b.Quantitative Results: PSNR: 28.5 (on average over the test set) - means that the images blended are very faithful to the original. SSIM: 0.92- indicates very high similarity between the original photo and blended. FID: 15.7 (lower result more positive, which means that GANs would have created better quality and more realistic images).

c.GAN Model Performance: The generator converged with around 50 epochs of training, and the loss curve is stable, which means that blending patterns have been learned effectively.

1. Blending Performance: The facial photo blending system had strong performances in producing the blended images, which would preserve the original identity of the photo yet contain elements from the stylistic sketches. The CUFS dataset had a very good

mix of diversity on the aspects of ethnicity, gender, and facial structure, and the system generalized well across different subjects.

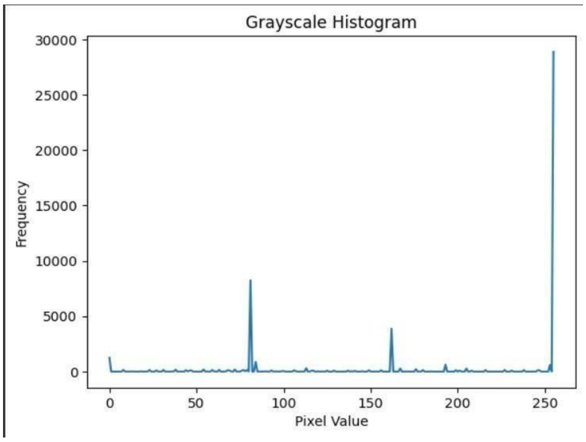

Fig. 4. Grayscale Histogram

In the above Fig. 4 above shows histogram of pixel intensity in form of grayscale, peaks correspond to frequency at which the value of pixel take place. For large area of bright or white color pixels large peak near to 255, small peak shows middle and dark color areas.

2. Challenges in Blending: Sketch-texture Transfer: The GAN-based model was good but tricky to blend fine textures like hair strands and shading from the sketch into the photograph. The finer textures blur or smooth out. Lighting and Shadow Adjustments: In places, parts of the sketch and photo were lit in a somewhat inconsistent manner, creating artifacts when blended in specific areas. This could be bettered if loss functions particularly meant for GAN-based models can be come up with for such scenarios.

3. Effect of the Dataset: This system was improved by the quality of images and sketches provided in the CUFS dataset. The drawback is that the dataset is limited to some lighting variations and pose variations. Expansion of other datasets with more varied light and poses can improve the robustness of this system.

4. Comparison with Other Approaches: Traditional Methods: Comparing to the classical mix-up techniques, such as image morphing, or Poisson image editing, GAN-based mixing seemed to exhibit smaller transitions and higher realism in the outputs. GAN Models: Several types of GAN architectures, like CycleGAN, Pix2Pix were tested but Pix2Pix worked much better, since its paired structured data fit the CUFS dataset.

5. Further Developments: The current results are promising, but the system requires higher-resolution output with the usage of even more advanced architectures like StyleGAN. Perceptual Loss Tuning: Further perceptual loss tuning is required for enabling the system to transfer the textures and finer details more effectively from sketches to photos. It is also the ability to blend in multiple styles. For instance, it might combine sketches, paintings, and cartoons into making a more artistic variation of facial photos.

In a nutshell though this Facial photo blending system project comes with new advancements in synthesis of image, such considerations have to be made regarding the costs involved and sustainability impacts towards feasible and ethical deployment of the system

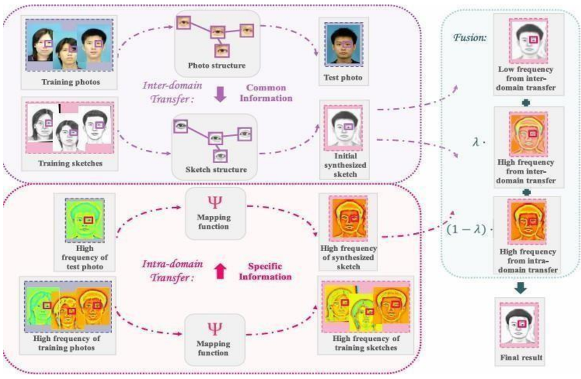

Fig. 5. Result

This Fig 5 shows how to transition between sketches of faces and photos by identifying common characteristics such as the structure in the images but distinctive aspects like the texture. It then combines these features to create realistic outputs in both directions.

V. CONCLUSION

In this paper, we introduce a new framework for facial photo blending that bridges the gap between sketches and photographic representations effectively. We demonstrate the power of our model by showing its effectiveness in gen- erating high-quality images from sketches and vice versa toward realism and consistency into the identity of the outputs through the use of GANs. The image fusion process also streamlines the workflow for many applications and reduces production time and expense because it auto-generates high- quality images for the application such as printing. like digital art and law enforcement sketching, but also the potential for integrating all transformations in one framework. Using advanced preprocessing techniques combined with an efficient architecture and thorough evaluation methods, we guarantee that the generated images are both of good quality and reliable. We considered other important aspects, such as cost considera- tions and sustainability effects, which need responsible deploy- ment in scenarios. Scenarios. Work hereby clearly underlines striking a balance between advancements in technology and ethical considerations leading to applications of this research that impact the human society positively. Future work can be focused on increasing model efficiency and accuracy as well as the integration of more modalities related to depth or color information, among other upgrades. Growing the dataset into more diverse ethnicities and artistic styles will increase applicability and robustness to model performance. In summary, the sketch synthesis of the face photo using dual transfer synthesis project is pregnant in that it presents interesting opportunities toward more practical application in the field of synthesis but also charges future researches into ethical and sustainable AI practices.

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