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Review of Forensic Facial Reconstruction in Crime Investigation

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ABSTRACT Crimes are carried out all around; these crimes include murder, robbery, assault, etc. These illegal actions endanger public security and safety. Following a crime, detectives frequently depend on eyewitness testimony to provide vital information. At a crime scene, eyewitnesses could remember information about the look of the criminal, including the form of the eyes, nose, mouth, and other characteristics defining a person. While law enforcement personnel need questions to identify suspects, conventional hand-drawn pictures usually fall short as they lack much information. This lack of clarity can complicate research and slow down the identification process. These hand-drawn depictions can be transformed into realistic photos to significantly increase the effectiveness of criminal investigations, therefore addressing this issue. Modern imaging technology lets law enforcement personnel generate more accurate visual profiles depending on eyewitness evidence. The more exact identification of face features is made possible by color photos capturing a greater spectrum of tiny details. This technology not only speeds up criminal solving but also significantly increases public safety.

INDEX TERMS Eyewitness testimony, Facial features, Hand-drawn Images, Realistic photos

I. INTRODUCTION

Crime is one of the most widespread problems that can be found anywhere in the world. It is a problem that transcends cultural, geographical, and social barriers, encompassing people and communities around the world. A criminal act is an action for which an individual is punished for violating the law, and it is subject to the penalties imposed by different countries. Individuals, families, communities, and society as a whole are all affected by crime, which can take many forms and can be classified into two categories: petty crimes and serious crimes. The necessity of conducting effective investigations into criminal activities has become more important as the crime rate continues to rise. Investigations are an essential element in both public safety and law enforcement. The types of criminal activities are numerous, such as property crimes, violent crimes, and cybercrimes, each of which poses a threat to society and is classified as a type of criminal activity. Cases of violent crimes include murder, assault, and others. There is widespread agreement that murder is one of the crimes that has the greatest impact on society worldwide.[1] The occurrence of these cases constitutes a blatant violation of human rights and poses a significant threat to public safety. The role of law enforcement agencies is essential for public safety and the functioning of the criminal justice system, as it helps in identifying suspects. The role played by law enforcement agencies is important for protecting the general public. In order to accurately and quickly identify individuals suspected of committing a crime, this job requires the use of a wide range of legal and technical methods and tools. [2] Legal authorities gather information from a wide range of sources, such as witnesses, field investigations, and physical evidence. Criminal sketches of suspects are created based on witness descriptions by specialists using forensic art. [3] A graphic representation of an unidentified person or an important person is created based on the memories and details provided by witnesses or victims. This can be done using the information provided by either party. Professionals in the art of drawing create sketches of individuals accused of being involved in the crime. Forensic artists conduct interviews with witnesses or victims to gather specific information about the person they saw [4]. The content may include details about the suspect's facial features, hair, clothing, tattoos, scars, and other physical characteristics that can be used to identify the person. The precise description of the human form can be transformed into a graphic representation by skilled forensic artists, which can be used as evidence in legal proceedings and investigations related to criminal activity. The methods that are executed manually or with the help of a computer are used by legitimate artists. [5]

Drawings are used as supporting evidence to back up other types of existing evidence, such as fingerprints, testimonies, or tangible artifacts. After completing the hand-drawn illustrations, they are distributed to the media to help identify and apprehend the person responsible for the crime. It is [6]. Contemporary identification methods, especially those that rely on forensic illustrations, can show errors due to the subjective nature of eyewitness testimony. Due to these restrictions, law enforcement agencies are unable to quickly identify and apprehend suspects involved in committing crimes. In the fields of forensic science and law enforcement, colored images are useful because they allow the transformation of suspect sketches derived from witness testimonies into realistic drawings, which can help in identifying and apprehending criminals.

II. RELATED WORK

Forensic investigation has lately attracted a lot of interest, particularly in relation to face recognition and photo translation of sketches. Technological developments have let academics investigate creative ideas to improve the accuracy and efficiency of criminal identification. With an eye toward some of the earlier research, this part summarizes the body of knowledge on turning sketches into color photos.

Shikang Yu et al. presented a generative adversarial network (GAN) that performs a face sketch-to-photo translation, taking advantage of CycleGAN and conditional GANs. [7] This paper described creating a new feature-level loss function that was merged with the traditional image-level adversarial loss function to increase the quality of produced images. Extra data provided by the generator and discriminator aids network training. Aside from the synthetic face picture, the network's discriminators receive a genuine image from the other modality as input, which serves as auxiliary information. Within the feature space, a feature-level loss penalizes the disparities between an original and treated image. Because of its efficiency in Pix2Pix, a method commonly used for image processing [8], the generator employs the U-Net architecture [9]. The discriminator comprises three convolutional layers. SSIM 0.5517 was combined with the CUHK Face Sketch FERET Database (CUFSF) [10].

Sreedev Devakumar et al. converted pencil drawings into realistic photographs for forensic analysis in order to ascertain an individual's identity. The deep convolutional generative adversarial network (DCGAN) transformed the sketch image into a realistic image [11]. The model is composed of a generator network (G) and two discriminator networks (D1, D2). Images are generated by the photo generator. The principal discriminator is a patch GAN, which calculates the L1 loss or discriminator loss. Due to this, the generator will activate the second discriminator after a cumulative total of 30 epochs. The second discriminator is a conventional model that incorporates an additional dense layer. The secondary classifier establishes a connection between the image generated by the target and the target photograph. The proposed network design includes a patch GAN as one of its discriminators. Standard discriminators that incorporate an additional dense layer are the alternative. Batch normalization and a ReLU layer are implemented by the conv2D generator. Batch normalization and a leaky ReLU layer are implemented by the discriminator, Conv2D. The discriminator uses 4x4 filters with a stride of two for each convolution. The generator utilizes 3x3 filters with a stride of 2. The G Generator enhances the quality of generated images by integrating six convolutional sequences and utilizing an augmented U-Net architecture, which incorporates DCGAN. The CUHK Face Sketch FERET Database (CUFSF) dataset was utilized in this endeavor, resulting in a final average SSIM of 0.587 [12].

Lidan Wang et al. presented Photo-Sketch Synthesis using the Multi-Adversarial Networks (PS2-MAN) technology, which involves iteratively transforming low-resolution photos into high-resolution images using an adversarial process. This study involves adversarial supervision at all resolution levels. Specifically, the feature maps at each deconvolution layer use 3 x 3 convolutions to provide outputs of varying resolutions. Two generator sub-networks, GA and GB, carry out the conversions from photograph to drawing and sketch to photograph. The Genetic Algorithm (GA) accepts a genuine facial photograph as input and produces a synthetic image as output. GB plans to turn sketches into pictures. The generator sub-networks' goal is to create images that closely resemble genuine ones in order to confuse the discriminator sub-networks. The goal of discriminatory subnetworks is to improve the capacity to distinguish between manufactured and authentic samples. The CUFS and CUFSF datasets are widely used in this study [13]. The CUHK Face Sketch Database (CUFS) contains a comprehensive collection of sketches. The collection includes 188 faces from the Chinese University of Hong Kong's (CUHK) student database, 123 from the AR database, and 295 from the XM2VTS database [14]. The SSIM for picture synthesis was 0.7915, while for sketch synthesis, it was 0.6156 [15].

Sparsh Nagpal et al. introduced a new contextual generative adversarial network designed specifically for sketch-to-image production. Using a drawing as a loose restriction, they found the most similar mapping and established their objective function, which combines a traditional GAN loss with a contextual loss. They also take a clear approach to the early

phases of sketching. According to this study, painting produces a picture on its own. A mask warps a small section of the input image. The image, which is partially obscured by a mask, serves as context. The model aims to provide a comprehensive view of this situation. The researchers employed seven up-convolutional layers, each having a kernel size of four and a stride of two. Every up-convolutional layer is followed by a batch normalization layer, which is designed to accelerate the training process and increase learning stability. The reputation linear unit (Relu) activation is used at all levels. Finally, we apply the tanh function to the output layer. The finished photos were fed into a layer of pre-trained GFP GANs trained with low-quality portrait enhancers. Even a simpler model can produce more realistic outputs and enhance the quality of the image. The dataset comprised the AR database, the XM2VTS database, and the CUHK Face Sketch database (CUFS), with an SSIM of 0.78 [16].

Sumit Gunjate et al. introduced a method for translating sketches into graphics using generative adversarial networks. Transforming an individual's representation into an image that incorporates the associated attributes necessitates the use of several types of machine learning techniques. The models comprised a GAN discriminator that only functions as a classifier. The task requires distinguishing between true information and data produced by the generator. The generator component of a generative adversarial network (GAN) gains the ability to generate synthetic data. It gets the ability to identify its output as authentic. Unlike discriminator training, generator training requires a greater degree of integration between the generator and the discriminator. The generator model used the U-Net architecture, which includes encoder and decoder layers. The model takes a picture (the sketch) as input and uses seven encoding layers with filters (C64, C128, C256, C512, C512, C512, C512, C512) to minimize its dimensions. Their research aims to determine whether the created facial structures, if deemed believable, have the same identity label as real faces. The researchers designed a lightweight CNN to extract identity-preserving characteristics and used the L2 norm for comparative analysis. [17]

III. DISCUSSION

We provide an overview of sketch-to-image transformation strategies, highlighting different methodologies, strengths, and drawbacks of chosen works in this field. The selected papers use various generative models to handle the issues of converting sketches into realistic images as shown in table I.

TABLE I Comparison of Different Methodologies

Ref #	Publication Year	Methodology	Strengths	Weaknesses
[15]	2018	Implements a multi-adversarial network framework for synthesizing facial images from sketches.	Achieves high-quality output and is applicable in various contexts.	Complexity in training multi-adversarial networks may lead to instability and high computational cost.
[10]	2019	Utilizes adversarial networks to enhance face sketch recognition accuracy.	Significantly improves recognition rates compared to traditional methods.	May require large datasets for effective training.
[16]	2022	Uses a multi-GAN approach to translate sketches into face images and enhance their quality.	Enhances fidelity and detail in generated images.	Complex architecture, potentially slower processing.
[12]	2023	Employs DCGAN architecture to convert forensic sketches into realistic images.	Produces high-quality, realistic images from sketches.	Limited by the initial quality of the sketches, sensitive to input variations.
[17]	2023	Applies a GAN model to transform sketches into detailed images.	Simple and effective methodology for sketch transformation.	Requires large datasets for training, sensitive to input quality.

IV. CONCLUSION

In conclusion, the inclusion of advanced imaging technologies—especially generative adversarial networks (GANs)—has greatly improved the process of turning eyewitness sketches into realistic images. This invention solves the limits of conventional hand-drawn sketches, which sometimes lack clarity and detail, therefore impeding efficient criminal investigations. Modern techniques allow law enforcement to produce more precise visual profiles of suspects, therefore enhancing the effectiveness of spotting and capturing offenders. By raising the possibility of crime solving and missing person locating, the developments in this field not only speed the investigative process but also contribute to more public safety. The possibility of these technologies improving the general efficiency of law enforcement and further honing forensic techniques looks bright as research develops.

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