Investigation and Morphing Attack Detection Techniques in Multimedia: A Detail Review

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Abstract

Multimedia forensics is an emerging field that focuses on the analysis of digital media to identify and authenticate digital evidence. It is a rapidly growing field that is being used in a variety of applications, including law enforcement, intelligence gathering, and digital forensics. This paper provides an overview of the current state of multimedia forensics and examines the various techniques used to detect and analyze digital evidence. This work examines the challenges associated with the use of these techniques and provides an overview of the current research in the field. Multimedia forensics involves the analysis of digital media to identify and authenticate digital evidence. This includes the analysis of images, audio, video, and other digital media. In addition to being widely used in special effects for entertainment, it is also used in computer vision and digital media. In this article, we investigated various morphing detection methods, techniques, and approaches in multimedia, i.e., image and video. Examinations of the number of "critical sites" are to be identified for successful morph detection as well as potential issues are included in the detailed description of the algorithms employed. Despite being one of the oldest methods, the mesh warping method is highly efficient. Facial recognition systems are susceptible to various biometric assaults because modern picture modification is now possible due to advancements in technology. In this study, the latest morphing attack detection techniques (MADT) approaches are compared and analyzed. On a variety of source picture databases, the effectiveness of various MADT methodologies is also contrasted. This work lists the limitations, benefits, and drawbacks of each morphing approach as well as how to generate morph images. Results are examined and contrasted with an in-depth analysis that sheds light on the weaknesses of current systems. The

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information presented in this paper is crucial for creating an advanced morphing attack detection scheme.

Keywords: identity recognition system; morphing; biometrics; morphed identities; forensics; digital forensic.

Introduction and Background

Online services, such as social and professional networking sites, get an estimated 1.8 billion photographs and videos daily (Wang, R., Juefei-Xu,2020). Yet, between 40 and 50 percent of these photos and films appear to have been altered either for friendly (such as photos that were modified for magazine covers) or hostile causes (e.g., propaganda or misinformation campaigns) (Godage, S. R., Løvåsdal,2022). Multimedia forensics is a field of study that focuses on the analysis of digital media to detect, identify, and authenticate digital evidence (Dolhansky, B., Bitton,2020). It is an important tool for law enforcement and other organizations that need to investigate digital evidence. Around 180 airports worldwide use these systems (Ferrara, M., Franco,2018). In addition, border control systems using digital technology are also common (Peng, F., Zhang,2019). Through digital systems, these systems verify facial identities. Live photo identification is matched with machine-readable travel documents, i.e., a passport (Scherhag, U., Rathgeb,2019). The live captured face must match the identity on the approved travel document to gain entry into that territory. It is clear that digital technologies ease the need for constant travel, and these systems are created to help a huge number of travelers. Many procedures have been simplified by technology.

There are also some negative aspects to it. This technology is being used by many evil minds for fraudulent activities. There is always a loophole in every technology solution that can be exploited. Some people can gain unauthorized entry into restricted territories by exploiting digital systems. Using face morphing attacks, these face recognition systems can be fooled. Various techniques for morphing images have been used since the 1980s (Yip, A. W,2022). Morphing attacks have become a growing concern in the field of multimedia security due to their ability to deceive biometric authentication systems. Traditional techniques rely on handcrafted features, such as texture analysis, edge detection, and shape analysis, to detect morphing attacks (Gao, S., Liu,2020). A morphing attack involves creating a hybrid image by merging two or more images to generate a new image similar to the original images. However, it is different enough to bypass the biometric recognition system. On the other hand, deep learning-based techniques have gained popularity in recent years due to their ability to learn complex features automatically.

Several deep learning-based approaches have been proposed for morphing attack detection, including convolution neural networks (CNNs), generative adversarial networks (GANs), and Siamese networks (Hu, Y., Xie,2020). These types of attacks are particularly concerning in applications such as border control, banking, and access control, where biometric authentication systems are commonly used to grant access to secure locations or accounts (Naveen, S. N., Hanumanthappa,2020). Moreover, over the past few years, researchers have suggested various techniques for detecting morphing attacks in multimedia (Zhang, Y., Cao,2021). Additionally, researchers have proposed using multi-modal biometric systems that combine multiple biometric modalities, such as face, iris, and fingerprint, to increase biometric authentication systems' security against morphing attacks. These techniques can broadly be categorized into two categories: traditional and deep learning-based techniques. Recent research has focused on developing more robust morphing attack detection techniques that are resistant to adversarial attacks and can detect advanced morphing attacks (Wang, Z., Feng,2021).

In addition, the authors' work (Mahajan, S., Sharma,2021) proposed a hybrid descriptor-based morphing attack detection framework through an ensemble of deep learning classifiers. The literature (Yadav, R., and Rathore,2022) reviewed face morphing attack detection methods using deep learning techniques. Authors (Silva, D. C. D., and Figueiredo,2021), proposed a morphing attack detection framework using a multi-channel convolutional neural network. Authors (Singh, R. K., Singh,2021), proposed an ensemble deep learning-based morphing detection approach in face recognition systems. Authors (Agarwal, S., Khan,2022), described a novel morphing attack detection technique using an ensemble of convolutional and feature pyramid networks. Authors (Pan, Y., and He,2021), presented a morphing attack detection framework that uses adversarial examples to improve its robustness. The Authors (Abdullah, M. F. B,2021), proposed a morphing attack detection framework using deep features and an extreme learning machine.

The researchers (Singh, A., Saha,2021) proposed a morphing attack detection framework that uses attention-based Siamese networks. Authors (Maity, S., & Banerjee,2022), provided a review of deep learning-based morphing attack detection techniques. Authors (Shaker, A. W. A. M. A., 2021) proposed a morphing attack detection framework that uses enhanced LBP features and deep learning. The work proposes a variety of morphing attack detection techniques using deep learning-based approaches, such as hybrid descriptors, ensemble deep learning models, attention-based Siamese networks, and extreme learning machines. Some works focus on specific types of morphing attacks; such as face morphing attacks or multi-channel morphing attacks.

Additionally, some works propose using adversarial examples for more robust morphing attack detection, while others focus on enhancing existing features, such as local binary patterns (LBP), to improve the accuracy of morphing attack detection. Moreover, the literature in (Singh, R., Kumar,2021), (Biswas, A., Pramanik2020), (Ghosh, S., Das, P.,2021), (Maraba, M. E.,2021), (Talip, F. A., Alasfour,2021) proposes various morphing attack detection frameworks using deep learning-based approaches, such as convolutional neural networks (CNNs), triplet loss, and ensemble deep networks. Additionally, some works propose two-stage classifiers for more robust morphing attack detection. One work focuses specifically on face-morphing attacks and provides a comprehensive survey of face-morphing attack detection methods. Technology breakthroughs can be used for illicit acts as well as for legitimate approaches. In the modern era, everyone has access to technology, and image morphing tools/programmers can be adopted to change photos of people's looks.

The contributions of this paper are:

• This paper discusses the morphing steps and techniques in multimedia to improve the detection process.

• It examines the challenges and limitations of morphing data repositories used for attack detection.

• In this paper, several morph detection tools, approaches, and their shortcomings in multimedia are analyzed and explained.

• This work displays the morphing evaluation measures/matrices that are often used in the industry.

• This research work provides a deep understanding and analysis of morphing and morph attack avoidance strategies and the outcomes of those techniques on various datasets and multimedia.

• This research also examines several attack detections for multimedia morphing.

• It also outlines the field's unresolved problems and potential directions for future research.

This paper will provide a detailed review of the various techniques used in multimedia forensics, including image analysis, text analysis, video analysis, audio analysis, and morphing detection. Moreover, this work discusses the challenges associated with each technique and the potential solutions. Finally, the paper will provide an overview of the current state of the art in multimedia forensics and discuss the future of the field. It involves the use of specialized techniques to analyze digital media such as audio, text, video, and images. The goal of multimedia forensics is to identify and authenticate digital evidence to support criminal investigations, civil litigation, and other legal proceedings. Multimedia forensics involves the use of a variety of techniques to analyze digital media.

Digital image analysis involves the use of tools to examine the content of digital images, such as pixel values, color histograms, and image content. Audio analysis involves the use of tools to examine the content of audio recordings, such as spectral analysis and sound localization. Video analysis involves the use of tools to examine the content of video recordings, such as motion tracking and facial recognition. Metadata analysis involves the use of tools to examine the metadata associated with digital media, such as EXIF data and GPS data. Multimedia forensics is an important tool for law enforcement and other legal professionals. It can be used to identify and authenticate digital evidence, which can be used to support criminal investigations, civil litigation, and other legal proceedings. It can also be used to detect and prevent digital fraud and other malicious activities. (Wolberg, G. Image morphing2018)

The composition of this paper is as follows; Section 2 presents the up-to-date multimedia morphing techniques and morph attacks detection techniques (MADTs). Sections 3 and 4 contribute to the databases and resources, and evaluation matrices, respectively. It also presents the evaluation metrics of the domain. Sections 5 and 6 present the proposed morph attack detection techniques. Section 7 discusses features extractions and comparison while Section 8 introduces the results and discussion and Section 9 concludes this work.

Multimedia Morphing Techniques

Attacks using morphing images and faces can have severe repercussions, similar to terrorism. According to reports, such hacks were successful in fooling the border control system to get unauthorized authorizations. As a result, the scholarly community has given this issue a lot of attention during the past few years. In the recent past, numerous techniques have been developed to recognize face-morphing attacks. In today's research, data are essential. For research purposes, numerous face recognition datasets have been compiled and made available to the public. However, there are extremely few publicly accessible morphing attack datasets. Warping and combining known as cross-fading make up most morphing algorithms. A straightforward cross-fade is probably what would come to mind as the most straightforward approach to create a seamless transition from one image to another. In its simplest form, cross-fading entails assembling a sequence of frames from linear combinations of the two source images. The intensity of a pixel at x as depicted in equation (1) (Liu J, 2012).

$$(x, y, n) = \left[\frac{n-1}{N-1}\right] I_f(x, y) + \left[\frac{N-n}{N-1}\right] I_i(x, y) \quad (1)$$

The majority of image processing software already has code for handling linear combinations of color images in a way that appears natural to the eye, even though doing so necessitates slightly more challenging operations for color images. However, compared to the seamless, organic shift discussed in the preceding section, the results of this process are considerably different. The outcomes of applying a straightforward crossfade to two photos of faces are shown in Figure 1.

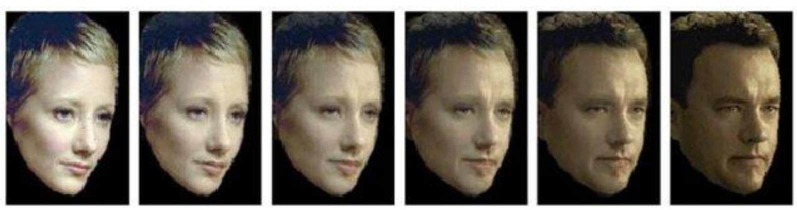

Figure 1: Women's faces morphed into men's (Liu, J.,.2019).

Even though the initial photos are relatively comparable, the features are out of alignment, resulting in intermediate images that don't look like one face as intended but rather like two faces superimposed. If the source photos had a drastically different shape or size, the outcomes could be expected to be far worse. A cross-fade between two faces is depicted in Figure 1. The intermediate frames in this sequence are incredibly blurry and lack any distinguishable quality; a video of this progression would only appear blurry with no feeling of motion.

Basic Morphing Process

The basic morphing process involves two main steps image registration, image interpolation, and final morph.

1. Image registration: This step involves aligning the two images that need to be merged, by matching corresponding points on

both images. This ensures that the final morph will be seamless and the images will blend smoothly.

2. Image interpolation: Once the images are registered, the next step is to create a series of intermediate images that gradually transform from one image to the other. This is done by using mathematical algorithms to calculate the colors and shapes of the pixels in each intermediate image, based on the corresponding pixels in the original images (Knoche, H., & Riegler,2018).
3. Final morph: The final step is to combine all the intermediate images into a single animation that shows the gradual transformation from one image to the other. This animation can then be played back at a smooth frame rate, creating the illusion of a seamless transition between the two images.

Basic Morphing Techniques

1. Interpolation: This technique involves gradually transitioning one image into another by blending the two images over time. This can be done using mathematical algorithms such as linear interpolation or spline interpolation (Knoche, H., & Riegler,2018).
2. Cross-dissolve: This technique involves gradually blending one image into another by gradually increasing the opacity of one image while decreasing the opacity of the other (Chiang, C. T., & Chen, 2015)
3. Warp: This technique involves manipulating the shape of an image to create a new image. This can be done by using mathematical algorithms such as Bezier curves or spline interpolation.
4. Distortion: This technique involves manipulating the shape of an image to create a new image. This can be done by using mathematical algorithms such as perspective distortion or lens distortion (Kim, Y., & Choi,2018).
5. Blending: This technique involves blending two or more images to create a new image. This can be done by using mathematical algorithms such as alpha blending or additive blending
6. Feathering: This technique involves blending the edges of an image to create a smooth transition between two images. This can be done by using mathematical algorithms such as Gaussian blur or box blur (Song, X., Li,2021).

7. Displacement Map: This technique involves using a separate image as a map to control the displacement of pixels in the original image. This creates a more complex and detailed morph.
8. Shape Layers: This technique involves using shape layers in image editing software to create masks that are used to reveal or hide parts of an image. This can be used to create more complex morphs (Vasconcelos, F. A., & Vasconcelos2021).
9. Keyframe Animation: This technique involves using keyframe animation to control the movement and position of elements in an image. This can be used to create realistic morphs [34].
10. Blending Modes: This technique involves using blending modes in image editing software to combine two images in different ways. This can be used to create interesting and unique morphs.
11. Combining Techniques: Many morphing techniques can be combined to create even more complex and interesting morphs. This can be achieved by using multiple layers, blending modes, and keyframe animation (Zhang, X., Song,2019).

Overall, morphing is a powerful technique that allows for the creation of realistic and seamless transitions between images and can be used in a variety of applications such as film, animation, and video game development. Basic morphing consists of warping and cross-fading algorithms from scratch. The cross-fading algorithm was chosen to be as straightforward as feasible. While cross-fading some sections of the image before others can produce fascinating patterns, it opted to combine the entire image simply and linearly as mentioned in the previous section. The original morphing method created by Smythe, mesh warping, is the foundation of the warping algorithm employed here. The features are simply recognized using a set of related points in this technique. (Sandwell, D. T.,2015) Later methods enable the user to pick matching lines or even free-form shapes, for instance, the outline of a skull, however, it was decided that these created too many technical difficulties to be practical for this inquiry.

The ease of the interpolation stage is one of the main advantages of the mesh and warping technique. This stage's goal is to map out every pixel's journey from the starting point to the finished product. These mappings can be created using scattered data interpolation, a common computational technique with a wide range of practical solutions because the features are single points. Figure 2 illustrates how a mapping is made. The report's provided morphs were interpolated using a technique known as "biharmonic spline interpolation" (Mullens, S., & Notley,2006) This was selected because it is a built-in feature of the Matlab programming environment, which was utilized for this project, and because it was shown to yield somewhat better results than bicubic interpolation.

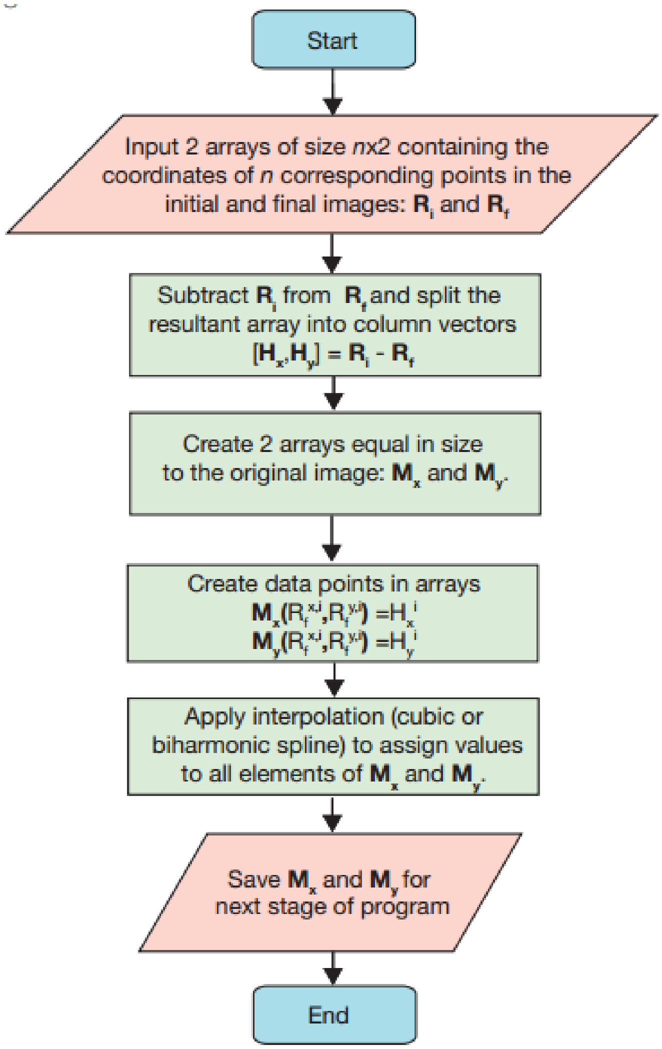

Figure 2: A flowchart illustrating the procedure for creating mapping arrays to explain each pixel's movement based on the user-selected points (Mullens, S., & Notley,2006).

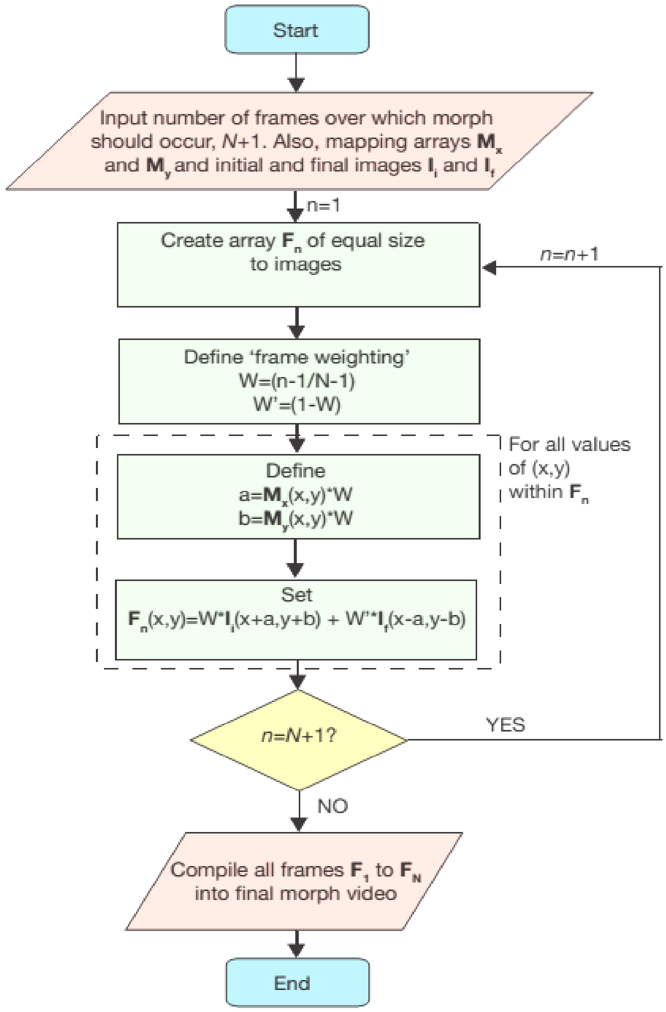

Figure 3: A flowchart demonstrating how mapping arrays can be used to create a whole series of frames that can be combined to create a morph (Mullens, S., & Notley,2006).

Once a mapping has been determined, creating a morph is a fairly simple process. The mapping should just be applied sequentially to alter the features in the original image to those in the final image and vice versa. The final morph is created by combining these two sequences using a linear cross-fade. Figure 2 and 3 for a grayscale image provides a more thorough explanation of the morphing entire process.

Image Morphing

In the 1980s and 1990s, animated movies and entertainment videos used photo morphing to produce graphical effects (Smythe, D. B.1992). Two or more faces must be used for the picture to morph. Creating a spatial correlation between the two subjects is the first stage. After that, intensity and warping interpolation are utilized to obtain the morphing. Thus, the combined photo of the two originals under discussion is similar to both of them. Different outputs of varying quality are produced using transition control parameters. Parameters for warping and interpolation are included in these controls. In the literature, there are numerous approaches utilized for image morphing. The list consists of radial basis morphing field morphing (Beier, T., & Neely,1992) and meshes warping (Zhang, H., Venkatesh,2021).

Control points are established using the face landmark mesh grid. The perspective image is altered into the final face by stilling a portion of the subject face and warping around the remaining portion of the under-study face image. Field morphing links the subjects using a similar set of lines. Calculating the distance from the predetermined line allowed for the plotting and establishment of distinct elements in the pictures. The mesh of points or curves is also used in the radial basis function (RBF) morphing technique. By comparing face photos, certain points or curves are found. The mapping process is then carried out through these locations and patches. Such morphs are made using the expert tool Fanta Morph.

The intermediate and ultimate outcomes of morphing using the given tool are shown in Figure 4. Recent years have seen a lot of development in generative adversarial networks. These techniques are also used to create faces that change (Venkatesh, S., Zhang,2020). These morphs are extremely reliant on the generative adversarial networks' generational characteristics. Furthermore, if the generative adversarial network is brand-new or unidentified, it may seriously jeopardize morph detection. These deep-learning morphing can be quite difficult for facial recognition algorithms, depending on these variables.

Image Morphing Steps

Image morphing is the process of transforming one image into another through a gradual series of intermediate images. Here are the general steps involved in image morphing (Sim, T., Baker, S.,2003), (Martínez, A., & Benavente,1998), (Yin, L., Chen,2008), (Ma, D. S., Correll,2015), (Kasiski, A., Florek,2008), (Grgic, M., Delac,2015),

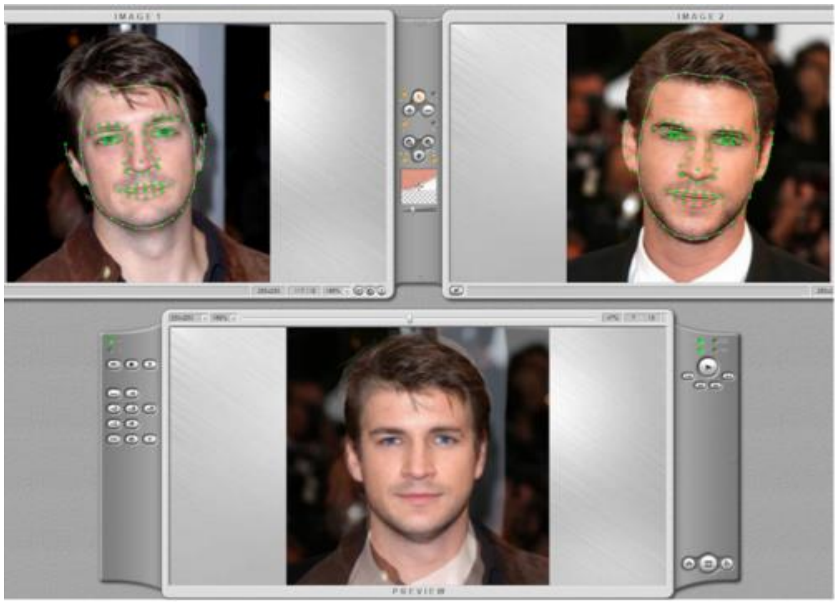

Figure 4: Intermediate and ultimate outcomes of image morphing using Fanta Morph (Panetta, K., Wan,2020).

1. Collect the input images: The first step is to choose the two images that you want to morph between. These images should have similar sizes and feature correspondences, which will make it easier to morph between them.
2. Define Correspondences: Define correspondences or matching points between the two images. These correspondences should be selected in such a way that they describe the same features in both images. (Senthilkumar, R.,2014)
3. Triangulation: Triangulate the corresponding points in each image to create a mesh. This mesh will be used to warp the images and create the intermediate frames. (Kannala, J., & Rahtu,2012)
4. Warping: For each intermediate frame, warp the mesh from the source image to the target image. This is done using a technique called "inverse distance weighted interpolation", which computes the warped position of each pixel based on the positions of the corresponding mesh vertices.
5. Morphing: Create the intermediate frames by blending the warped source and target images, using a parameter called the "morphing parameter" to control the degree of blending between the two images (Hamza, M., Tehsin,2022), (Raghavendra,

R.,2016), (Venkatesh, S., Ramachandra2020), (Smith, S. W,1998).
6. Output: Finally, output the intermediate frames as a sequence of images or as a video.

These are the basic steps involved in image morphing. Depending on the specific application, there may be additional steps or variations on these steps. (Bebis, G., Georgiopoulos2006)

Image Morphing Techniques

1. Cross-dissolve morphing: This technique involves blending two images by gradually increasing the opacity of one image while decreasing the opacity of the other (Mudur, S. P,2006), (Hossain, A., Chakraborty,2020).
2. Delaunay triangulation morphing: This technique involves dividing each image into a series of triangles and then morphing each triangle individually to create a smooth transition between the two images. (Besl, P. J., & McKay,1992)
3. Bezier curve morphing: This technique involves creating a series of Bezier curves that match the key features of both images, such as eyes, nose, and mouth. These curves are then used to morph one image into the other. (Zhu, S. C., & Yuille,1996)
4. Twining: This technique involves creating intermediate frames between two images to create a smooth transition. It is commonly used in animation and video production. (Szeliski, R.,2006)
5. Radial basis function morphing: This technique involves using a mathematical function to morph one image into another. It is commonly used in medical imaging and computer vision applications. (Shrivastava, A., Pfister,2017)
6. Affine morphing: This technique uses mathematical transformations to morph one image into another. It involves transforming the shape and position of the image, but not the size.
7. Non-rigid morphing: This technique involves deforming one image to match the shape of another image. It is often used to morph faces or bodies and is commonly used in animation and special effects.
8. Hybrid morphing: This technique combines multiple morphing techniques to create a more realistic and seamless transition between images. For example, a combination of affine and non-

rigid morphing may be used to morph a person's face while also adjusting their position and size.

9. Deep Learning Morphing: This technique utilizes deep learning algorithms to generate the intermediate images between the two images being blended. This results in more accurate and realistic morphing results.

Audio Morphing

Audio morphing is a technique used to blend two or more audio samples to create a new sound or speech. This can be done using a variety of techniques, including time-domain techniques, frequency-domain techniques, and vocoding. One example of audio morphing is to blend the voices of two different people to create a new, hybrid voice. Another example is to blend the sounds of two different instruments to create a new, hybrid instrument sound. Audio morphing is used in a variety of applications, such as music production, voice synthesis, and sound design. Hatch defines such audio manipulations as "working with sound forms to realize a progressive shift from one sound item to another." A recent focus of research in the realm of computer music is audio morphing (Wu, Z., Zhang,2018)

Audio Morphing Steps

Audio morphing is the process of transforming one audio signal into another through a gradual series of intermediate signals. Here are the general steps involved in audio morphing (Alves, A. X.,2019), (Kong, J., Huang, Y.,2017), (Peeters, G., Giannoulis,2018), (Spors, S., & Dörfler,2018), (Zhang, X., & Kim,2018), (Roads, C.2019).

1. Collect the input audio signals: The first step is to choose the two audio signals that you want to morph between. These signals should have similar properties such as sampling rate, bit depth, and duration.
2. Analyze the input signals: Analyze the input signals to extract relevant features such as pitch, timbre, loudness, and spectral content.
3. Time-frequency representation: Convert the input signals into a time-frequency representation such as a spectrogram or a wavelet transform.
4. Feature matching: Match the features extracted from the input signals using a suitable algorithm such as dynamic time warping, correlation, or mutual information.

5. Cross-synthesis: Use cross-synthesis techniques such as phase vocoding, additive synthesis, or granular synthesis to blend the input signals based on the matched features and create the intermediate signals.
6. Morphing: Create the intermediate signals by gradually varying the parameters used in the cross-synthesis process such as the mixing ratio, the time stretching factor, or the spectral envelope.
7. Output: Finally, output the intermediate signals as a sequence of audio files or as a single audio file with multiple sections.

These are the basic steps involved in audio morphing. Depending on the specific application, there may be additional steps or variations on these steps. (Jot, J. M., Arfib, D.,2017), (Tzanetakis, G.,2009).

Audio Morphing Techniques

The following are the basic audio morphing techniques presented in the literature (McPherson, A,2018), (Bhat, V. H., & Kumar2018):

1. Cross-synthesis: This technique involves blending two or more audio signals to create a new sound. This can be done using various software or hardware tools, such as granular synthesizers or spectral processing tools.
2. Formant shifting: This technique involves changing the formants of a sound, which are the resonant frequencies that give a sound its characteristic timbre. This can be used to change the pitch or timbre of a sound without changing its overall frequency.
3. Time stretching and pitch shifting: These techniques involve changing the tempo or pitch of a sound without changing its overall duration or frequency. This can be used to create new sounds or to match the tempo of a sound to a specific beat or melody.
4. Granular synthesis: This technique involves breaking a sound down into small grains, which can then be manipulated and reassembled to create new sounds. This can be used to create complex textures and sounds that are difficult to achieve with traditional synthesis techniques.
5. Spectral processing: This technique involves analyzing the frequency spectrum of a sound and manipulating specific frequency ranges to create new sounds. This can be used to create sounds that are not possible with traditional synthesis techniques, such as sounds with a wide range of overtones or harmonics

Video Morphing

A video is made up of several frames that are played quickly one after the other to create smooth motion. Due to the same movements that both moving faces make, this will concentrate on merging two motion graphics faces together. Video morphing is a technique used to blend or transition between two or more videos, creating a seamless transition between them. This is often used in film and television to create special effects or to blend between different shots. The process typically involves analyzing the features of the two videos, such as the position of facial features or key points on an object, and then using that information to create a smooth transition between the two. This can be done using software such as Adobe After Effects or other specialized video morphing software.

Video Morphing Steps

The following are the basic video morphing steps presented in the literature (Lee, J. H., & Lee,2006), (Yu, K., & Chen,2011)

1. Capturing the source images or videos: The first step in video morphing is to capture the source images or videos that will be used in the morphing process. These images or videos should be of similar resolution, lighting, and angle to ensure a smooth transition between them.
2. Identifying key points: The next step is to identify key points on the source images or videos that will be used as reference points for the morphing process. These key points can be facial features, body parts, or other distinctive features that will be used to align the images or videos.
3. Aligning the images or videos: Once the key points have been identified, the images or videos need to be aligned so that they match up perfectly. This step is important to ensure a seamless transition between the images or videos.
4. Creating a morph: Once the images or videos have been aligned, the next step is to create a morph. This is done by gradually blending the images or videos, using the key points as reference points.
5. Adjusting the morph: Once the morph has been created, it can be adjusted to fine-tune the transition between the images or videos. This may involve adjusting the speed of the transition, the amount of blending, or other settings.
6. Saving the final video: The final step is to save the final video, which will be a seamless blend of the source images or videos.

This video can be exported in various formats and can be shared on social media platforms. In Figure 5, the fundamental steps of video morphing are displayed.

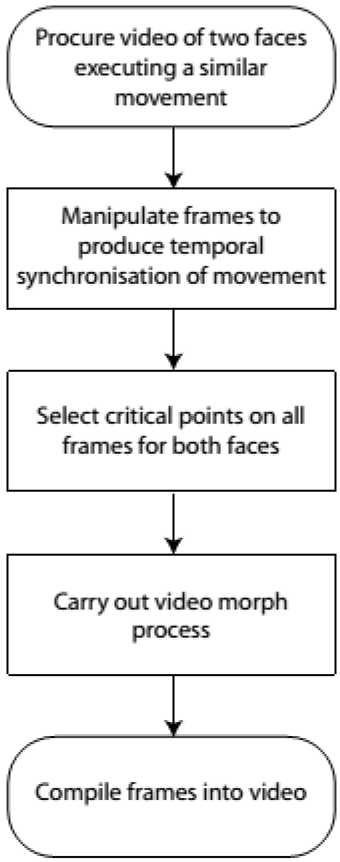

Figure 5: Video-based morphing process flowchart (Jiang, Y., Liu,2018).

The most challenging part of the video-based morphing process is finding two video sources whose frames correspond to the same or similar motion segments. Even while the morphing algorithm can readily join two out-of-sync frames, the resulting video would not have a smooth motion. Using this method, two videos that are often synchronized can be produced by two people performing a similar movement at almost the same speed. Then, to ensure that both videos have an equal number of frames, frames from both videos can be sampled at a specific rate. To select important points, the user must carefully examine each frame and recognize the points of interest. The two merged images will be out of alignment and the edges will be vague if the points chosen at this stage are bad ones. If the subject's mobility has caused certain facial features to move irregularly, critical points can simply be added to certain pairs of frames. It should be highlighted that crucial parts in the video sources only need to line up between opposing frames and not between consecutive frames.

Video Morphing Techniques

Video morphing is a technique used to blend two or more videos, creating a smooth transition between them. Several different techniques can be used to achieve this effect, including (Kokaram, A. C.,2017), (Li, C., Cao,2017)

1. Pixel-based morphing: This technique uses algorithms to calculate the position of each pixel in the two videos, and then creates a new frame that is a blend of the two. This technique can be used to create a smooth transition between two videos, but can also create a distorted or unnatural effect if not done correctly.
2. Feature-based morphing: This technique uses algorithms to track specific features in the two videos, such as the position of a person's face, and then creates a new frame that is a blend of the two. This technique can be used to create a more natural transition between two videos but can be more complex and time-consuming to implement. (Lu, J., Zeng,2017)
3. Warping: This technique uses algorithms to warp or bend the images in the two videos to create a smooth transition between them. This technique can be used to create a more natural transition between two videos, but can also create a distorted or unnatural effect if not done correctly. (Kokaram, A. C.,2017)
4. Layer-based morphing: This technique uses multiple layers of video and combines them to create a smooth transition. This technique can be used to create a more natural transition between two videos but can be more complex and time-consuming to implement.
5. Deep learning-based morphing: This technique uses deep learning algorithms to analyze the videos and create a smooth transition. This technique can be used to create a more natural transition between two videos but can be more complex and time-consuming to implement. (Li, C., Cao,2017)

Software and Resources for Morphing Videos

Software resources for video morphing are listed in Table 1.

Table 1

Software and some open-source resources for the morphing of videos. (Lu, J., Zeng2017), (Ahmad, W., Ahmed, S.,2020), (Ismail, A. A., Pathan2019), (Ghosh, S., & Pakray,2018).

	Software	***Description/Reference***
1.	Face2Face	A real-time facial reenactment method that can change facial expressions and movements in a target video by using the facial expressions from a source video.
2.	VOCA: Voice Operated Character Animation	A system that can synthesize realistic mouth movements for a character in a given video based on the audio of a voiceover.
3.	DeepFakes	A type of machine learning algorithm that can generate realistic synthetic videos by swapping faces or other visual attributes between different subjects
4.	OpenFace	An open-source facial behavior analysis toolkit that can perform real-time face detection, facial landmark detection, and facial expression analysis
5.	DeepFaceLab	A deep learning-based software that can create realistic deepfakes by swapping faces or modifying facial features in videos
6.	AVATAR-NET	A deep learning-based system that can generate high-quality 3D avatars from a single 2D image of a face [109].
7.	FaceSwap	A deep learning-based face-swapping system that can transfer facial features and expressions from one face to another in videos or images
8.	GANimation	A generative adversarial network-based system that can animate a still face image by generating facial expressions and movements in a realistic manner
9.	Neural Body Transformer	A deep learning-based system that can generate realistic 3D animations of human body movements and postures from a single RGB video
10.	Video-to-Video Synthesis (V2V-S)	A deep learning-based system that can perform image-to-image translation and generate realistic videos by modifying or transferring visual attributes between different video sequences

Text Morphing

Text morphing is the process of transforming one text into another text, usually through the use of computer algorithms. This can be done for various reasons, such as language translation, text generation, or text summarization. The process can involve changing the grammar, vocabulary, or structure of the text to create a new version that is different from the original. Text morphing can also be used to create new, unique texts by combining elements from multiple existing texts. It is often used in digital art and animation, as well as in security applications to protect sensitive information.

Text Morphing Basic Steps

The following are the basic text morphing steps presented in the literature (Husnain, G., Anwar,2023).

1. Select the starting and ending text: The first step in text morphing is to select the starting text and the ending text. These can be two different sentences or phrases that you want to blend.
2. Break down the text into smaller chunks: Once the starting and ending text is selected, the next step is to break down the text into smaller chunks, such as words or syllables. This will make it easier to blend the text.
3. Create a transition plan: Before you begin morphing the text, it is important to have a plan for how you want the text to transition from the starting text to the ending text. This can include things like blending words, changing the order of words, or adding new words.
4. Begin blending the text: Once the transition plan is in place, it is time to start blending the text. This can be done by taking words or syllables from the starting text and blending them with words or syllables from the ending text.
5. Test and adjust: After the text is blended, it is important to test the result and make any necessary adjustments. This can include things like changing the order of words or adding new words to make the text flow better.
6. Finalize: Once the text is blended and adjusted to your liking, it is time to finalize it. This can include things like cleaning up any errors or inconsistencies in the text and making sure it is grammatically correct.
7. Share: After finalizing the text, share it with others or use it in your project.

Text Morphing Techniques

The following is the text morphing techniques presented in the literature (Saeed, N., Ahmad, W.,2018), (Husnain, G., Anwar,2022), (Smith Micro Software,2023).

1. Interpolation: This technique involves smoothly transitioning between two different texts by gradually blending their characteristics. It can be used to create a gradual transition from one language to another or from one style of writing to another.

2. Substitution: This technique involves replacing specific words or phrases in a text with other words or phrases that have similar meanings. This can be used to change the tone of a text or to make it more appropriate for a different audience.
3. Stylization: This technique involves applying a specific writing style or formatting to a text. This can be used to make a text more formal or informal or to make it more suitable for a specific genre or audience.
4. Randomization: This technique involves randomly changing elements of a text, such as the order of sentences or the use of certain words. This can be used to create a sense of unpredictability or to add a sense of humor to a text.
5. Hybridization: This technique involves combining elements of two different texts to create a new text. This can be used to create a new narrative or to add a new perspective to an existing text.
6. Addition: This technique involves adding new words or characters to a text string to create a new, longer version of the original text.
7. Deletion: This technique involves removing certain words or characters from a text string to create a new, shorter version of the original text.
8. Machine Translation: This technique involves using a machine learning algorithm to automatically translate a text string from one language to another.
9. Text-to-Speech: This technique involves converting a text string into speech by synthesizing the sounds of the words in the text.
10. Speech-to-Text: This technique involves converting speech into a text string by transcribing the spoken words. (Waqas Ahmad, Ghassan Husnain,2023)

Database and Resources

The literature on biometrics and facial recognition has a large number of datasets. The databases and related work details about resources with MADTs methodologies are listed in Table 2. Each dataset with subject, images and feature extraction with techniques are described for MADTs model training and testing. To produce morphed photos for use in MADT studies, these databases and tools are used. Many databases have a wide variety of image varieties. To build a general MADTs model, high image variety is preferable. The quantity of subjects makes it easier to train a strong and general model. Additionally, the total amount of photos in a particular database is quite important for training and evaluating a model. The making of morphed photographs involves the use of several morphing techniques. Studies that have made use of sizable databases with lots of variation and a range of morphing technologies present a more accurate picture of MADTs.

Table 2

Data and related work details about resources and databases with MADTs methodologies. (G., & Anwar,2022), (Khattak, N. Y., Hussnain2023), (Ullah, T., Hussnain2023)

Datasets	Subjects	Images	Images/Subject	Features Extraction	Techniques/Tools
FRGCv2 [28, 5]	4003	28021	7 per subject	Illumination, 3D and expression	UBO Morpher [5], FaceMorpher-2018, GIMP Software-2017, Sqirlz Morph-2017, OpenCV [47], FaceFusion.
FERET [41, 36]	1119	14126	Variable per subject	Various face stances and illumination in grayscale and color, varying racial backgrounds, facial hair, and hairstyles	FaceMorpher-2018, OpenCV [41], UBO Morpher, and FaceFusion-2012. [5] Sqirlz Morph-2017, GIMP Software-2017. Triangle warping, the Beier-Neely field morphing technique [36], and Fotomorph.
FM-DB (Custom Made) [3]	63	1149	23 per subject	Expression, omission, cosmetics, and gender	Designed morphing methods and Script-based Coding [3].
FRAV-ABC [50]	1170	2340	2 per subject	Gender and Age	Sqirlz Morph and GIMP Software-2017 [50].
AR Face [46]	126	4000	Variable per subject	Eyelashes, a scarf, a facial expression, light	Sqirlz Morph [28] and GIMP Software-2017,
BU-4DFE [41]	101	60600	600 per subject	Race, expressions, and gender	Triangle-warping tools/method [37], Beier-Neely field morphing techniques, and Fotomorph [49].
SC-Face [43]	130	4160	Variable per subject	Quality, race, gender, distance, illumination, posture	Triangle-warping, Beier-Neely field Tools/method [38], and method of Fotomorph [51].

Faculty of Industrial Engineering [21,49]	200	2800	14 per subject	Facial, different poses, illumination change, expression variety, eyelashes, and varying races	Triangle-warping tools, Beier-Neely field morphing method [21], and the Fotomorph method[49].
CFD [41]	597	597	1 per subject	Gender and race	Triangle-warping tools, Beier-Neely field morphing tools/method [33], and Fotomorph[50-51].
PUT [42]	100	9971	Variable per subject	Posture, high resolution	OpenCV method[53]
Utrecht-2008 [37, 53]	69	131	Variable per subject	Expression, race, and gender	Triangle-warping tool, and Fotomorph-2014/Beier-Neely field morphing method [37]. Custom-based Made [53]

Morphing Databases

The following are the morphing databases for 3D models, animations, and visual effects.

1. Zygote Body: This database contains 3D models of human anatomy that can be used for morphing and animation.
2. Maximo: A cloud-based platform that allows users to upload their 3D models and apply animations and morphs to them.
3. Poser: A software package that includes a library of 3D characters and props, as well as tools for creating morphs and animations.
4. Autodesk Maya: A popular 3D animation and modeling software that includes tools for morphing and animation
5. Blender: An open-source 3D modeling and animation software that includes tools for creating morphs and animations.
6. Daz Studio: A free 3D animation software that includes a library of 3D characters and props, as well as tools for creating morphs and animations.
7. 3D Morph: A database of 3D models and morphs that can be used in animation and visual effects.
8. Turbosquid: A marketplace for 3D models that includes a wide variety of morphable models
9. Sketchfab: A platform for 3D models that includes a library of morphable models that can be used in animation and visual effects.

1. Reallusion iClone: A software package for creating 3D animations that include a library of morphable models and tools for creating animations and visual effects (Husnain, G., Anwar2023), (Sketchfab Inc2023).

Evaluation

For evaluating the effectiveness of morph detection systems, different assessment criteria have been published in the literature. The evaluation metric could cause some crucial elements to be overlooked while accentuating others. The most frequently employed measures for this problem domain are the attack presentation classification error rate acronym as APCER, the detection equal error rate acronym as DEER, the Bonafede presentation classification error rate acronym as BPCER, and the average classification error rate acronym as ACER. APCER [51] is the proportion of morphing attacks that are anticipated to be real.

$$1 - \left(\frac{1}{|\mathrm{MA}|}\right) \sum_{\mathrm{w}=1}^{\mathrm{MA}} \mathrm{Rw} \qquad (2)$$

Here, Rw has a value of one if an attack is accurately identified as an attack and zero otherwise. |MA| is the total morph attack numbers. The fraction of valid incidents incorrectly labeled as morph attacks is known as BPCER [51].

$$BPCER = \frac{\sum_{w=1}^{BF} Rw}{|BF|} \qquad (3)$$

Here, |BF| represents all instances of genuine samples. Rw is one when a picture is declared to be authentic and zero when it is not. The average of the two above values is known as ACER

$$ACER = \frac{APCER+BPCER}{2} \qquad (4)$$

The point on which the trade-off detection curves of BPCER and APCER are the same is known as DEER.

Methods of Morph Attack Detection

Various techniques can be used to detect distorted images depending on the data and computing power available. There are two main sorts of MADT.

Single-Image MADT

Single image MADT assesses the input image as genuine or morphed based solely on the study of the morphed image. It takes advantage of the traces and artifacts that morphing an image leave behind. These traces are employed to identify morphing. Similar to binary statistical image features [48], texture analysis could be highly useful in identifying those artifacts. Additionally, deep-learning-based is a fantastic technique for identifying these morphing attacks. But to train, such systems need a steady stream of data. The effectiveness of MADT approaches depends on the quality of the data (Reallusion Inc2023).

Method of Differential MADT

Two photos must be processed for the differential MADT approach to work. The inquiry image is one, while the traveler's live image is the other. Both photos are used in morphing attack detection and analysis. For evaluation, vectors-based features of the two required images are required. De-morphing is the procedure for finding the conspirator. The two photos shown above can also be used for de-morphing. By taking the question image and the live picture out, the accomplice image may be found. For morph attack detection, the differential morph attack detection approach is widely used in many investigations. The following literary devices are frequently used (Farid, H.2009)

Morphing detection techniques

The following are the morphing detection techniques presented in the literature.

1. Image comparison: This technique involves comparing an image or video of an object or person to a reference image or video to detect any changes or morphing that have occurred. This can be done using algorithms that compare pixel-by-pixel or feature-by-feature.
2. Motion tracking: This technique involves tracking the movement of an object or person in a video to detect any changes or morphing that have occurred. This can be done using algorithms that track the movement of specific features, such as facial features or body parts.
3. Object detection: This technique involves detecting specific objects or features in an image or video to detect any changes or morphing that have occurred. This can be done using algorithms that are trained to recognize specific objects or features, such as faces or cars.
4. Deep learning: This technique involves using deep neural networks to detect changes or morphing in an image or video. This can be done by training the neural network on a large dataset of images or videos to detect specific features or changes.

5. Watermarking: This technique involves embedding a watermark or signature into an image or video to detect any changes or morphing that have occurred. This can be done by adding a digital signature or watermark to the image or video that is difficult to remove or tamper with.
6. Shape Detection: This technique uses shape-based algorithms to detect morphing in images by comparing the shape and contours of the objects in the image.
7. Feature Extraction: This technique uses various features such as texture, color, and edge detection to extract features from the image, which are then compared to detect any changes or morphing [100].
8. Neural Network-based Detection: This technique uses deep learning algorithms such as convolutional neural networks (CNNs) to detect morphing in images.
9. Hash Function-based Detection: This technique uses a hash function to generate a unique signature or code for the original image, which can be used to detect any changes or morphing in the image.
10. Digital Forensics: This technique involves analyzing the digital artifacts left behind in an image to detect any morphing or tampering. This includes analyzing the file format, metadata, and other technical details of the image. (Bradski, G.1998)

Image De Morphing Methods

In picture de-morphing methods, the genuine identity of the document's owner is ascertained using both captured photographs and potentially altered images. To accomplish its purpose, the de-morphing model applies mathematical modifications to the prospectively altered and static/motioned-based images. The de-morphing approach makes it feasible to connect a probably altered photo on the passport or other identity documents to the digital image of the passenger, process the information, and identify the true owner of the travel document. During the de-morphing phase, the morphing process is turned around.

A morphed image is essentially a linear combination of images captured by an accomplice and a criminal (the person who owns the documents, i.e., passport, identity documents, etc.), where the criminal's image is the photo taken at the border, whereas the accomplice's image is the photo used to combine it with the criminal's image to create the modified image. To determine the de-morphed image, the live-taken image must be subtracted from the potentially altered image displayed on the identity document. Let's assume that a test comparing the performance of a de-morphed image and a live image capture produces a subpar result. In that case, it signifies that the travel document's image, rather than being the traveler's actual image, is a morphing image. Let's assume that a test comparing the performance of a de-morphed image and a live image capture produces a subpar result. In that case, it signifies that the travel document's image, rather than being the traveler's actual image, is a morphing image. The basic operation of a de-morphing-based morph attack detection model is shown in Figure 6 (Viola, P., & Jones,2011).

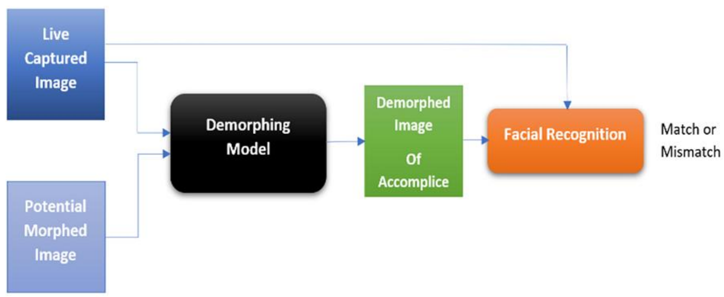

Figure 6: Basic operation and method of the de-morphing model, MADT (Viola, P., & Jones,2011)

Feature Extraction and Comparison

Using the deep-learning technology dubbed a deep-based face model; features are extracted from the live image as well as perhaps edited photographs throughout the feature extraction process. The features gathered are used to categorize the machine-learned query photographs. The differential morphing attack detection tool has been used extensively in the previous literature by employing various feature extraction and comparison methodologies. Given in was a trustworthy differential-based MADTs method that correctly identified altered images produced by 4 various morphing-based techniques. The basic process block of a diff-based MADT model is shown in Figure 7. Test images included print-scanned, scaled, raw, and JPG copies of the original photos (Szegedy, C.,2015).

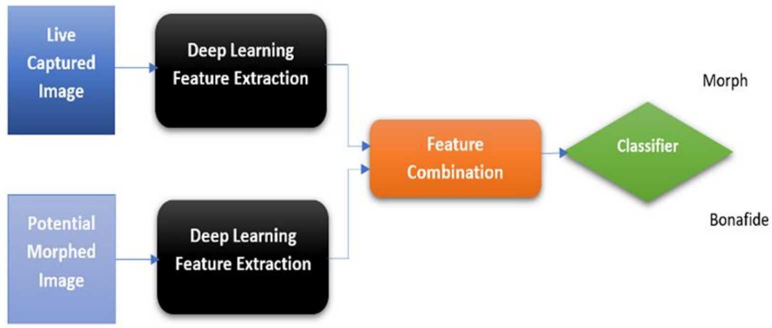

Figure 6: Basic method and process block of differential MADT. (Szegedy, C.,2015)

Results and Discussion

The research community has recently put up notable MADT methodology proposals. To attain the highest level of accuracy with varied datasets, numerous strategies have been adopted. For the generation of morph images, many tools have been employed. The produced morphing photos have undergone several pre-processing techniques to eliminate artifacts. Table 2 provides a summary of prior work for comparison and analysis. There isn't much-documented research with really striking findings. However, the majority of the outcomes presented come from less difficult data. The lighting and facial expressions in experimental data are monotonous. For experimentation, very little data about eyewear and headgear has also been supplied. Another obstacle to accurate morph recognition is facial hair.

The published study to date completely or partially ignores these difficulties. The morphing pictures may also be produced using dynamic weight ratings for various subjects. The morphed photos utilized in these experiments only combine a maximum of two people. The majority of studies in the literature ignore photos with eyeglasses or headgear. The experimentation also makes use of very high-quality photographs. Low quality will make detection difficult due to noise artifacts. The use of only two-morph photos is another serious issue. Very likely, the attacker will employ n-morph pictures with different weight contributions. If $n > 2$, it will be harder to find N-morph pictures. Additionally, it is anticipated that straightforward scripts and programmers like OpenCV, FaceMorpher, and Face Fusion are utilized to create morphs. The accuracy is good since it is simple to identify the resultant pictures. (Cox, I. J.,1997), (Goodfellow, I., Bengio2016), (Thies, J., Zollhöfer,2016), (Zhou, T., Brown,2018).

Conclusion and Future Work

The problem of morphing attack detection has been addressed using several strategies, and astonishingly effective outcomes have been obtained by utilizing various image/media processing methods and deep learning tools/algorithms. Various resources, databases, and tools/techniques have been investigated, and various criteria are utilized to assess the effectiveness of the tests. In the research, deep face depictions with a DEER of almost 1 percent to 7 percent produced the best morph detection outcomes. Similar to this, additional works with DEER of 0.78 percent to 20 percent and DEER of 2.8 percent to 3.1 percent also produced extremely good results. The most recent methods in the area were provided in this review. Although there has been a lot of progress in the industry, there are still a few issues that need to be resolved in further study. It is vital to have a sizable data bank that has a range of pictures that are representative of real-world situations. There must be challenging situations, such as those involving facial hair, glasses, makeup, different hairstyles, facial expressions, and shifting postures.

Additionally, there is virtually little age variance in the data. The passport document is valid for 5-10 years by ICAO guidelines regarding travel papers. However, the dataset only provides a two-year variance. Therefore, datasets/ resources with an age variation of up to 10 years must be used for the studies. It is recommended to use images with a range of varied characteristics, such as the participants' age, emotion, and position, as well as the lighting, gender, race and hair, beard, and eyeglasses. To improve the efficiency of border control checkpoints, generalized photographs should be taken into consideration. Furthermore, the majority of research generates morph data using subpar morphing software. Realistic instances need the use of more advanced tools. Additionally, this research might be useful for banks, security organizations, hotels, and criminal investigations. Additionally, the laws governing picture dimensions and other image requirements vary per nation.

Multimedia may differ in quality depending on the technology used to capture them. Therefore, these obstacles must be overcome for the MADTs strategies to be used anywhere. This is due to a variety of acquisition techniques, illumination setups, objects, and technological advancements. To recreate a real-world scenario while testing the model, high-quality professional morphing tools should be utilized to produce high-quality morphed multimedia. If this suggested model is effectively built and put into practice, a robust, adaptable, generalized, and accurate model will be ready for deployment in any travel or security organization. Additionally, it will demonstrate that dishonest behavior won't be tolerated. It has also been highlighted that the morphing identification process does not employ three morphs. The challenge of morph detection will increase if three or more subjects are used to construct the morphs. This might lead to a fresh path of research into the problem.

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