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A Brief Review of AI-generated Virtual Humans

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Abstract—*Generative AI has revolutionized the way we create and manipulate digital content, including the creation of highly realistic virtual humans. This paper provides a comprehensive overview of the recent advancements in generative AI and its applications in creating realistic virtual humans. We first delve into the concept of generative AI and its capabilities in generating unique images and manipulating existing media. We then discuss the various techniques and methods used in creating AI-generated virtual humans, including 3D face reconstruction. Furthermore, the paper delves into the current challenges and ethical considerations surrounding the field, providing valuable insights for researchers and practitioners in the field. The paper also explores the various applications of AI-generated virtual humans in industries such as gaming, entertainment, and education.*

Index Terms*—omputer Generative Art and Music, Computer generating content, GANs, Generative Adversarial Net-Works, AI-generated mediaomputer Generative Art and Music, Computer generating content, GANs, Generative Adversarial Net-*
Works, AI-generated mediaC

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I. INTRODUCTION

Creating virtual humans has several motivations. One of the main reasons is the ability to use them as avatars in virtual reality and augmented reality experiences, allowing users to interact with digital characters in a more immersive way. Additionally, virtual humans can be used for training and simulation in fields such as medicine [1], military, and education. They can also be used as digital assistants, customer service representatives, or even as virtual news anchors in the media industry. Furthermore, in the entertainment industry, virtual humans can be used in video games [2], movies, and animations, allowing for more realistic and expressive characters. With the advancements of AI, virtual humans can be generated in high level of realism and can be used in various fields, which makes it a promising technology. [3]. The advancement in AI technology has brought about significant economic growth and has impacted various aspects of daily lifes [4]. The integration of AI in the manufacturing industry has greatly improved efficiency and performance in various aspects, from workforce planning to product design, resulting in increased productivity, enhanced product quality [5]. The integration of AI has not only improved efficiency and productivity but also brought forth new opportunities and possibilities, playing a significant role in driving social progress and propelling society into a new era of development [6]. One such area of opportunity is the creation of virtual humans and characters, which thanks to the power of generative AI, can now be created faster and more easily than ever before.

A. Generative AI

The concept of using computers to produce various forms of media, such as art and music, dates back to the 1950s. However, early attempts at generative AI were limited in their ability to replicate human creativity and resulted in output that was easily distinguishable from human-generated content. With the advancement of AI and machine learning technologies, the realism and sophistication of generated content has greatly improved over the years. Today, we see generative AI being used to produce highly realistic images, videos, and even 3D models of virtual humans, which are able to mimic human behavior and expressions. This technology has a wide range of applications, from entertainment and gaming to education and metaverse [7] [8].

Generative AI allows for the creation of unique and previously non-existent images, such as human faces, as well as the ability to manipulate existing media for experimentation and exploration. This technology has a wide range of applications, such as the instant translation of film and TV into various languages [9] (refer to figure 2), the ability to alter an actor's appearance to any age [10], and the creation of realistic virtual humans through the integration of natural facial features , voice, and lip-syncing [11] [8].

Generative AI has proven to be a powerful tool for creating virtual humans and characters. By using methods such as 3D face reconstruction and AI-generated content, developers are able to create realistic and highly-detailed virtual humans and characters with greater speed and convenience than ever before. Additionally, the ability to manipulate current media and generate images of objects that have never existed before opens up new possibilities for experimentation and innovation [12] [13].

B. AI-Generated Characters - Deepfakes

The term AI-generated characters, also known as deepfakes (realistic rendering of human faces, voices, and characteristics) refers to characters that have been created with artificial intelligence technology. The characters appear in a variety of forms, including virtual assistants, non-playable characters in video games, and even autonomous robots. They are created to behave like humans and respond to user inputs, providing a more realistic experience than traditional non-playable character models [14]. The development of AI-generated characters is made possible through advances in natural language processing, deep learning algorithms, facial recognition software, 3D face reconstruction, and other related technologies that allow computers to recognize landmarks of faces in images or videos.

AI-generated characters are popular in the gaming industry because they offer an immersive experience for players and allow developers to create unique content without manual programming or animation [15]. The ability to create realistic and engaging characters using AI has the potential to revolutionize the way we experience and interact with media, offering new possibilities for entertainment, education, and beyond [16].

One of the main challenges in generating realistic characters using AI is the need to capture and reproduce the wide range of physical and behavioral traits that make humans and other beings unique. This requires advanced techniques for modeling, animating, and rendering characters, as well as sophisticated algorithms for generating and controlling their behaviors and interactions [17]. In order to generate realistic face of the characters, computers employ 3D face reconstruction.

One potential application of AI-generated characters, or deepfakes, is in the field of entertainment, where they can be used to create highly realistic digital avatars or to insert actors into movies or television shows post-production. This can be useful for a variety of purposes, such as creating virtual assistants, animating characters in video games and movies, and more [16].

Another potential application of AI-generated characters is in virtual reality, where they can be used to create more immersive and realistic experiences for users. For example, an AI-generated character could be used as a virtual tour guide, leading users through a virtual museum or other location. AIgenerated characters could also be used as virtual assistants or companions in virtual reality, providing users with a more human-like interaction [18].

In the field of education, AI-generated characters could be used to create virtual tutors or teachers, providing personalized instruction and feedback to students. This could be particularly useful for students in remote or underserved areas, who may not have access to traditional in-person education. AIgenerated characters could also be used to create interactive educational content, such as virtual lab simulations or virtual field trips [19].

One potential use of AI-generated characters in the medical field is in telemedicine, where they could be used to create virtual assistants or companions for patients. These AI-generated characters could provide patients with information about their condition and treatment, as well as emotional support. They could also be used to communicate with patients remotely, allowing doctors and other healthcare providers to monitor their progress and provide care without the need for in-person visits [1].

Creating a virtual human character that is anatomically and photometrically plausible is a challenging task. One of the most important parts of a human-like character is its face, and in order to create a virtual human face, we have to use 3D face reconstruction.

Figure 1. Deepfakes example

C. 3D Face Reconstruction

3D face reconstruction refers to technology that creates three-dimensional model of a person's face from one or more two-dimensional images or videos [20]. It allows for the identification of individuals in images or videos for security purposes, the creation of digital avatars or animated characters, and the creation of immersive virtual reality experiences [21]. One way in which 3D face reconstruction can be used in the creation of AI-generated characters is by providing a highly accurate and realistic model of the face that can be used as the basis for the digital avatar [22]. By using 3D face reconstruction to create a detailed and accurate 3D model of a person's face, it is possible to create an AI-generated character that looks and behaves like a real person in a more convincing and realistic way [23]. 3D face reconstruction can be used to create digital avatars that are personalized to a particular individual, by using images or videos of that person's face to create the 3D model. This can be useful for creating virtual assistants or companions that are tailored to a particular user, or for creating digital avatars for use in virtual reality or other immersive experiences [24]. In virtual reality, 3D face reconstruction can be used to create digital avatars that accurately reflect the user's facial features and expressions. This allows for more natural and realistic interactions with other avatars or virtual objects in the virtual environment. It can also be used to create virtual reality experiences that are tailored to the user's facial features, such as virtual makeovers or virtual face-swapping [25].

II. CHALLENGES

One of the main challenges of 3D face reconstruction is the accuracy of the reconstruction, as it can be difficult to create a precise 3D model from 2D images or videos. This can be particularly challenging for images or videos with low resolution or poor lighting, as well as for faces with certain features or characteristics that are difficult to capture accurately. For example, the technology may struggle to accurately reconstruct faces with scars, facial hair, or glasses [26].

Another challenge of 3D face reconstruction or AIgenerated characters is the computational cost of the process, as it can be resource-intensive to create a 3D model from multiple images or videos. This can be particularly challenging for applications that require real-time processing, such as facial recognition or virtual reality. The computational cost of the process can also make it difficult to scale the technology to large datasets, such as databases of images or videos of large numbers of individuals. As the technology has the potential to be used to identify individuals without their consent. This can be a concern in applications such as facial recognition, where the technology may be used to track and monitor individuals without their knowledge. There are also concerns about the potential for the technology to be used for malicious purposes, such as creating fake videos or images of individuals.

In addition to these technical challenges, there are also regulatory and ethical challenges related to the use of 3D face reconstruction. There is a need for clear guidelines and regulations regarding the use of the technology, as well as mechanisms for addressing any potential abuses or misuses of the technology.

Ethical considerations related to the use of the technology, such as the potential for discrimination or bias in the use of 3D face reconstruction. For example, there may be concerns about the potential for the technology to be used to unfairly target or discriminate against certain groups of people [27].

Another ethical challenge related to 3D face reconstruction is the potential for the technology to be used to create deepfakes, which are fake videos or images that are designed to appear real. Deepfakes have the potential to be used for malicious purposes, such as spreading misinformation or defaming individuals. This can have serious consequences, as deepfakes can be difficult to detect and may be believed to be real by those who encounter them [28], for example Justin Bieber fooled into picking a fight with deepfake Tom Cruise [29].

III. TECHNIQUES

A. GANs

The GAN, or Generative Adversarial Network, is a type of machine learning model that consists of two neural networks working together. The generator network generates new content, such as images or videos, that are similar to the input data. The discriminator network, on the other hand, is responsible for determining whether the generated content is real or fake. The two networks compete against each other in a process called adversarial training, where the generator tries to create more realistic output, while the discriminator tries to better distinguish between real and fake data. This creates a feedback loop, where the generator and discriminator are constantly improving and creating more realistic output over time. GANs have been used in many applications such as creating realistic images, videos, and even creating realistic 3D characters. [8] [30]

B. 3D morphable face models (3DMMs)

3D morphable face models (3DMMs) is a technique used to create realistic virtual human characters in computer graphics and computer vision. The method is based on a statistical model of the shape and texture of human faces, which is created by analyzing a large dataset of 3D face scans or photographs. The model captures

the variation in facial shape and texture across different individuals, allowing it to generate a wide range of virtual faces that are anatomically and photometrically plausible [31].

To create a virtual character using 3DMMs, a set of facial features, such as the position of the eyes, nose, and mouth, are specified in a 3D coordinate system. The 3DMM then generates a corresponding 3D mesh of the face, which can be textured and animated to create a realistic virtual character. The technique can also be used to create a virtual version of a specific person by fitting the 3DMM to a set of photographs or scans of that person's face [32].

One of the main advantages of 3DMMs is that it allows for fine-grained control over facial features and expressions, which is important for creating realistic and expressive virtual characters [33]. Furthermore, the technique can be used to create virtual characters of different ages, genders, and ethnicities, making it useful for a wide range of applications. 3DMMs method is widely used in gaming, film and entertainment industries, but also in education and research.

C. Techniques for 3D Face Reconstruction

There are several techniques that can be used for 3D face reconstruction, including structured light, stereo vision, multiview stereo, photometric stereo, and shape-from-shading. Structured light involves projecting a pattern of light onto the face and using a camera to capture the deformation of the pattern caused by the shape of the face. The 3D shape of the face can then be reconstructed based on the deformation of the pattern. This technique is generally fast and accurate, but it may not work well for faces with certain features or characteristics, such as facial hair or glasses [34].

Stereo vision involves using two or more cameras to capture images of the face from different angles, which can then be used to reconstruct the 3D shape of the face. This technique can be effective for reconstructing the 3D shape of the face, but it may not work well for faces that are poorly lit or have low contrast [35].

Multi-view stereo involves using multiple images or videos of the face captured from different angles to reconstruct the 3D shape. This technique can be effective for reconstructing the 3D shape of the face, but it may be computationally intensive and may not work well for faces with certain features or characteristics, such as facial hair or glasses [36].

Photometric stereo involves using multiple images of the face captured under different lighting conditions to infer the 3D shape. This technique can be effective for reconstructing the 3D shape of the face, but it may not work well for faces that are poorly lit or have low contrast. Shape-from-shading involves using the shading patterns on the face to infer the 3D shape. This technique can be effective for reconstructing the 3D shape of the face, but it may not work well for faces that are poorly lit or have low contrast [37].

In summary, each of these techniques has its own strengths and limitations, and the best technique for a particular application may depend on the specific requirements and constraints of that application. In some cases, a combination of different techniques may be used to achieve the best results. One of the main factors to consider when choosing a technique for 3D face reconstruction is the accuracy of the reconstruction. It is important to choose a technique that is able to create a precise 3D model of the face. This is particularly important for applications such as facial recognition, where the accuracy of the reconstruction is critical.

IV. APPLICATIONS OF AI-GENERATED VIRTUAL HUMANS

A. Game application

The gaming industry has been at the forefront of embracing new technologies, and the integration of AI-generated virtual humans is no exception. The ability to create highly realistic, virtual characters has opened up a whole new world of possibilities for game developers. With AI-generated virtual humans, game developers can create characters that are more lifelike and have more complex behaviors than ever before. This allows for a more immersive gaming experience, where players can interact with characters that feel more like real people.

One of the most exciting applications of AI-generated virtual humans in gaming is in the realm of open-world games. These types of games allow players to explore vast virtual worlds, and interact with a wide variety of NPCs. With the use of AI-generated virtual humans, game developers can create NPCs that are more responsive to player actions and have more realistic behaviors. This leads to a more engaging and believable gaming experience, where players feel like they are truly living in a virtual world.

Another application of AI-generated virtual humans in gaming is in the area of multiplayer games. With the use of AIgenerated virtual humans, game developers can create NPCs that can compete against human players in real-time, providing a more challenging and dynamic gaming experience. This can also lead to more social interactions among players, as they can engage with NPCs that have more human-like behaviors. AI-generated virtual humans are also being used in the development of educational games. These games leverage AI-generated virtual humans to create interactive, engaging scenarios that teach players new skills and

knowledge. This can be especially useful in fields such as medicine, where players can practice diagnostic and treatment skills in a safe, virtual environment [38] [39].

B. Film industry application

The use of AI-generated virtual humans in the film industry has the potential to revolutionize the way movies are made. One of the biggest advantages of using AI-generated virtual humans is the ability to create highly realistic and detailed characters without the need for expensive and time-consuming special effects or makeup. Additionally, AI-generated virtual humans can be used to create characters that would be impossible to create with traditional techniques, such as creatures from fantasy or science fiction worlds.

Another major advantage of using AI-generated virtual humans in film is the ability to create characters that can be controlled in real-time, allowing for more flexibility and precision in the filming process. This can lead to more realistic and dynamic performances, as well as the ability to create scenes that would be difficult or impossible to film with traditional techniques.

Additionally, AI-generated virtual humans can also be used in post-production to create special effects and enhance existing footage. For instance, it can be used to create realistic digital doubles of actors, allowing for more efficient and costeffective stunts and action sequences. The technology also allows to de-age or age actors, which allow directors to use certain actors for a certain role in a film but through the application of the technology it can be used to represent a younger or older version of the character [39].

In short, the applications of AI-generated virtual humans in the film industry are diverse and varied. From creating new and exciting characters to enhancing existing footage, the technology has the potential to change the way movies are made and experienced.

C. Education

Artificial intelligence-generated virtual humans have the potential to revolutionize the field of education. One of the key applications is in the realm of language learning. By using AI-generated virtual humans, students can practice speaking and interacting with a virtual person who speaks the target language. These virtual humans can also be programmed to provide feedback and corrections, allowing students to improve their language skills in a more interactive and engaging way [40].

Another application of AI-generated virtual humans in education is in the field of virtual reality (VR) and augmented reality (AR) experiences. These virtual humans can be integrated into immersive educational experiences, allowing students to interact with and learn from virtual characters in

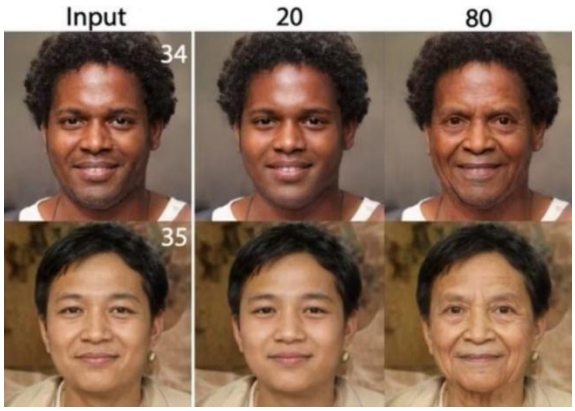

Figure 2. AI tool by Disney can make actors younger/Older instantly

a more engaging and interactive way. For example, a virtual human can be used as a virtual lab assistant in science classes, allowing students to conduct virtual experiments and interact with the virtual human for guidance and feedback [41] [42].

Moreover, AI-generated virtual humans can be used as personal tutors for students, providing one-on-one instruction and personalized feedback. These virtual humans can also be used to create interactive educational games, where students can learn and practice new concepts in a more engaging and interactive way [43].

Overall, the potential applications of AI-generated virtual humans in education are vast and varied, and they have the potential to revolutionize the way we learn and teach. As technology continues to advance, we can expect to see more and more AI-generated virtual humans being integrated into educational experiences, making learning more interactive, engaging, and effective [39].

V. CONCLUSIONS

Imagine a world where virtual humans seamlessly interact with us, enhancing our daily lives and revolutionizing industries - this is no longer just science fiction, but a reality thanks to advancements in artificial intelligence. AI-generated virtual humans have the potential to revolutionize various industries, including gaming, film, and education. In the gaming industry, AI-generated virtual humans can provide more realistic and immersive game-play experiences, as well as enable the creation of new types of games. In the film industry, AI-generated virtual humans can be used to create new types of movies and special effects, and can also be used to translate films and TV shows into different languages. In education, AI-generated virtual humans can be used to create interactive and engaging learning experiences, and can also be used to create virtual tutors and assistants.

Despite the potential benefits, there are also challenges to be addressed in the field of AI-generated virtual humans. These include issues related to the realism and believability of the virtual humans, as well as ethical concerns such as the potential for misuse of the technology. However, with continued research and development, these challenges can be overcome and the full potential of AI-generated virtual humans can be realized.

Overall, the paper presented an overview of the state of the art in the field of generative AI and AI-generated characters, 3D face reconstruction and the techniques used to create them, as well as their applications in gaming, film and education. The paper also highlighted the challenges and potential future directions of the field. It is clear that AI-generated virtual humans will play an increasingly important role in many industries in the coming years, and it is important to be aware of the current state of the technology and its potential future developments.

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