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The Future of Animation: Exploring the Integration of Generative AI and the Role of Animators

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***Abstract*--Artificial Intelligence (AI) capabilities significantly change the way creative actors in the production process work. Through a study of the impact of AI on the animation industry, this article highlights the shift of AI from basic automation to more complex roles. Multi-modal generative AI, such as Large Language Models (LLMs) and diffusion models, revolutionizes the animation workflow, changes the job description of animators, and creates new challenges and opportunities. The analysis is carried out on repetitive tasks such as in-betweening, rendering, and asset creation. Through the exploration of the application of diffusion models for the creation of image and video works, as well as the application of LLMs in the development of narratives and storyboards, animators are expected to focus more on conceptual aspects and increase their creativity. AI will be involved as an innovative partner. This partnership encourages various forms of new creative expression as well as collaborative and integrated workflows. It is undeniable that this leaves notes and challenges related to the potential shift in human resources and ethics. This article provides an explanation of the adaptations that must be made so that the integration of technology and humans can maximize human creativity, not to replace it.**

Key words: AI; Animation; Creative potential, Human-machine collaboration.

I. INTRODUCTION

It is undeniable that Artificial Intelligence (AI) has penetrated and influenced the production process in various industrial sectors, including the creative industry. Today's AI is no longer a futuristic trend; it supports and changes the way creative actors approach the work they will create [1]. The sophistication of AI technology can now handle and produce complex creative works [2], [3]. Looking back, the application of AI was limited to basic automation. However, with the advancement of Artificial Neural Networks in the field of Machine Learning, AI can take on more complicated roles and produce animated films. This forces artists in the animation industry to adapt and to be proactive in dealing with it [4].

The way animators work has changed significantly. The transformation of the production flow of animated films has changed the job description of the animators involved [5]. The involvement of AI in animated film production can provide various benefits, including production cost efficiency and creative exploration. However, AI capabilities can also threaten established roles [6], [7].

Multi-modal generative AI, such as Large Language Models (LLMs) and diffusion models, is forcing innovation in animation film production. Multi-modal generative AI can generate output through drawings, concept art, and videos. Diffusion models can produce highly detailed and realistic images, while LLMs show tremendous potential in terms of narrative, thus setting parameters in animated film production [8], [9].

Automation through the use of AI tools enables the revolutionization of the creative process. Automation in various technical tasks in the production flow of animated films can increase production speed. On the other hand, animators can focus more on conceptual aspects, such as basic ideas, themes, character designs, storylines, and visual styles [10], [11].

This research examines the future of collaboration between human animators and AI technology. Through a review of emerging frameworks and their impact on the animation industry, this research will explore emerging trends, multi-modal generative AI applications, the effect of AI on the role of animators, the challenges and opportunities of animator collaboration with AI, and strategies for creators to address the fusion of these two capabilities [4], [12], [13], [14].

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II. METHOD

Using a comprehensive literature review method, this research will analyze the integration of AI in the animation industry. The research process begins with identification, followed by searching and sorting relevant recent scientific articles, until analysis is carried out, as shown in Fig. 1.

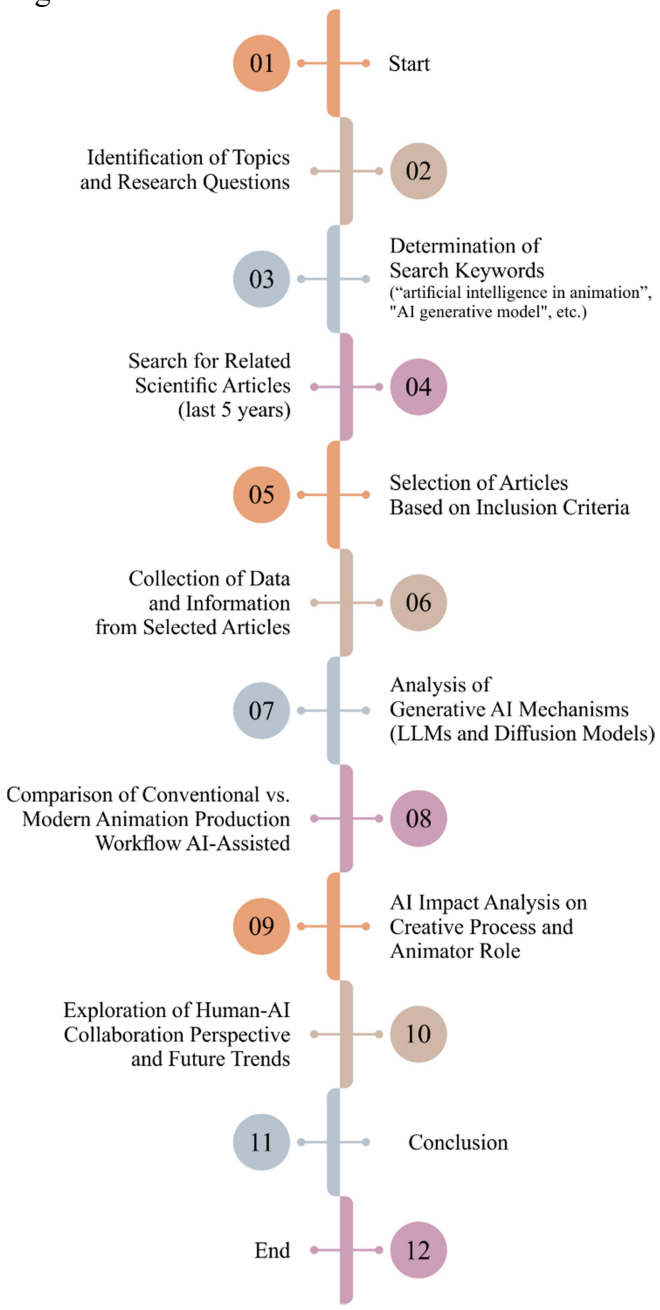

Fig. 1. Research steps

The search for scientific articles used the keywords "artificial intelligence in animation", "AI generative model", "AI diffusion model", "large language models in animation", "impact of AI on animation", "human-AI collaboration in animation", and "future of animation." The literature review method applied inclusion criteria, meaning articles within the last five years related to the research question were considered.

The seven keywords above cover the main dimensions to be analyzed, starting from the application of technology, its impact on professions, and the direction of future collaboration between humans and AI. The collected articles will explore the application of AI in various aspects of animation, both from the technical and artistic sides. A comprehensive discussion of the impact of AI on the production process, the role of animators, and changes in the work structure in the animation industry will also be revealed for analysis and evaluation.

This research explores the basic mechanisms of multi-modal generative AI: LLMs and diffusion models in generating outcomes. Various information about these models was collected and compiled through scientific articles and technical documentation. The research emphasized the ability of AI to create images, concept art, videos, and sequence animation.

To analyze the potential impact of AI on the creative process in animated film production, this research compares the conventional animated film production workflow with the workflow that involves AI. The question arises: How can AI automate tasks, such as in-betweening, rendering, and asset creation? How does this automation affect the job description of animators and other roles in animated film production? How can AI be utilized to enhance creativity rather than replace creators?

Various perspectives and views on the future of human-AI collaboration in the animation industry will be explored to identify possible frameworks and implications of these collaboration trends.

III. RESULTS AND DISCUSSION

A. Current AI Trends and Techniques in the Animation Industry

The animation industry is currently exposed to various AI tools that have significantly changed the production process. For example, AI can be used to animate characters, producing smooth and realistic movements without the intervention of animators in the manual keyframe process, frame

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by frame [9], [15], [12]. Deep learning models can realistically predict body movements, motion dynamics, facial expressions, and even lip synchronization. This significantly reduces production time, while on the other hand, it increases realism and creativity [10], [16]. In motion capture, AI plays a vital role in correcting errors, reducing noise, and filling in missing frames in motion capture data. And it is done automatically with increasing accuracy. So that the resulting animated work products are "cleaner" and more accurate [17], [18], [19].

Physics-based procedural animation is also inseparable from the influence of increasing AI capabilities. AI can display more complex effects for water, smoke, and cloth. AI tools can produce realistic simulations of natural elements such as flames, billowing smoke, flowing water, moving cloth, and explosions. In addition, AI supports scene and environment creation, allowing animators to produce a variety of scenes quickly, thereby increasing the efficiency of the animation production process. This means going back to the efficiency of the animation production process [6], [9].

The next contribution of AI is in terms of rendering optimization. AI significantly contributes to optimize lighting, textures, and shadows in real-time [20], [21], [22]. Machine learning algorithms can improve the quality of the resulting images, but with minimal computational load. Maximizing the use of AI means achieving high-fidelity visuals faster. AI also facilitates automatic asset creation and texture creation [23], [24]. Overall, the AI trend acts as a powerful tool, but not in its capacity to replace, but instead to support animators through the automation of various repetitive tasks and increased creativity [12], [25], [26], [27].

B. Application of AI Generative Model in Animation Production

Diffusion models are powerful tools for generating images and video synthesis. Diffusion models, which are advanced machine learning algorithms, can learn from the reversal of the process of adding noise to a dataset to produce high-quality data [28], [29], [30], [31]. In the animated film production, diffusion models such as Stable Diffusion, DALL-E, and Sora are known as text-to-image or text-to-video generative AI. They can produce images or videos in great detail and realistically according to the textual descriptions entered [32], [33], [34], [35]. Likewise, concept artists can quickly create visual illustration works that can then be used to convey ideas, designs, or moods of an animated film before production. In a short time, concept artists can create a variety of concept art in large quantities. Making the choice increasingly rich and agreeing upon it with the production team. In addition to illustration works, diffusion models can be used to create 3D environments and full-scale High Dynamic Range Image (HDRI) maps from textual input only. The impact is the reduction in the need for environment artists, and matte paintings made by environment artists become obsolete [36], [37], [38].

LLMs such as ChatGPT are at the forefront as tools that help scriptwriters and storyboard artists write scripts and storyboards. LLMs greatly assist scriptwriters in gathering ideas, expanding ideas, and presenting details of ideas from the film's initial concept to be produced [39], [40], [41], [42], [43]. LLMs can analyze scripts, identify key elements, and maintain the consistency of these elements, thus greatly assisting the storyboarding process. Another tool, Keyframer, is an AI tool supported by LLMs to generate animations from static images (in SVG format) with text commands, which can recognize everyday conversational language [44].

The Large Language Model for Mixed Reality (LLMR) emerged as a framework developed by LLMs to generate and modify interactive Mixed Reality experiences in real-time. This includes constructing 3D models rigged by translating natural language description input [45], [46].

Table I – III compares the animated film production workflow that is done conventionally with the production process assisted by AI. The term "conventional" in this table refers to the fact that all work done by conceptors, artists, and policymakers does not rely on AI assistance.

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TABLE I
Conventional vs. AI-Assisted Animation Workflow Comparison in Stage Pre-Production

Workflow Stage	Conventional	AI-Assisted
Concept and Ideation	Team brainstorming, manual research, creation of manual/ standard digital mood boards.	Text/ Ideas: ChatGPT (OpenAI), Google Gemini, Claude. Visuals: Midjourney, Stable Diffusion (via Leonardo.ai, DreamStudio, Automatic1111, ComfyUI), DALL-E 3 (via ChatGPT/ Bing).
Scriptwriting	Manual writing by writer/team.	Text: ChatGPT, Google Gemini, Claude, Sudowrite (fiction focus).
Character Design	Manual/digital sketching by artists, iterative revisions based on feedback.	Visuals: Midjourney, Stable Diffusion, DALL-E 3, Artbreeder (face/portrait focus).
Environment/ Background Design	Manual/digital sketching and painting by background artists.	Visuals: Midjourney, Stable Diffusion. Textures: Substance 3D Sampler (AI features), Poly.ai/ TextureLab (potential).
Storyboard	Manual/ digital drawing of storyboard panels by storyboard artist.	Visuals (panel-by-panel): Midjourney, Stable Diffusion. Specific Tools (varying): Storyboarder.ai, Krock.io (management + potential AI), Cascable Storyboard AI.
Animatic	Scanning/ arranging storyboard panels according to manual audio/ dialogue timing.	Video Editing: Runway (editing features), Adobe Premiere Pro (integrations). Synchronization (potential): Features in NLE software or specialized tools (still evolving).

TABLE II
Conventional vs. AI-Assisted Animation Workflow Comparison in Stage Production

Workflow Stage	Conventional	AI-Assisted
Layout	Placing characters and elements in scenes according to storyboards, determining camera movement (manual/digital).	Generally still manual, potential for AI feature integration in future layout/3D animation software.
Key Animation (Keyframing)	Animator manually/digitally draws/creates main key poses of movement.	Motion Capture: Rokoko Studio (AI motion capture/cleanup), DeepMotion. Core animation: Standard software (Toon Boom, Maya, Blender, etc.) - limited AI role.
In-betweening	Animator manually/ digitally draws frames between keyframes (time-consuming).	Video Interpolation: Runway (Frame Interpolation), Flowframes/RIFE/DAIN (desktop apps). Animation Software Features: Some AI tweening features in Toon Boom, Cacani. Style Transfer: EbSynth.
Line Cleanup/ Inking	Manual/digital tracing/cleaning of animation sketch lines frame-by-frame.	Software Features: Clip Studio Paint (some AI features), Photoshop (Neural Filters). Specific Tools (varying): Potential use of specialized AI models (still research).
Coloring	Manual/digital coloring frame-by-frame using a defined color palette.	Software Features: Clip Studio Paint (AI Colorize), Photoshop (Neural Filters - Colorize), TVPaint (plugins). Specific Tools: Style2Paints (if active). Petalica Paint.
Final Background Creation	Painting detailed backgrounds manually/ digitally based on designs.	Visuals/Textures: Midjourney, Stable Diffusion, Substance 3D Sampler (AI features). Upscaling: Topaz Gigapixel AI, Upscayl.

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TABLE III
Conventional vs. AI-Assisted Animation Workflow Comparison in Stage Post-Production

Workflow Stage	Conventional	AI-Assisted
Compositing	Manually combining various layers (characters, backgrounds, effects) using compositing software.	Software Features: Adobe After Effects (Content-Aware Fill, Roto Brush AI), Runway (Green Screen, Inpainting), Boris FX Suite (AI features), Nuke (CopyCat).
Editing	Manual editing of animation sequences, timing adjustments, adding transitions by an editor.	NLE Software Features: Adobe Premiere Pro (Scene Edit Detection, Auto Reframe), DaVinci Resolve (Neural Engine features). Text-based Editing: Descript.
Visual Effects (VFX)	Creating effects (fire, water, explosions) using specialized software, often manual or simulation-based.	Texture Generation: Midjourney/ Stable Diffusion. Simulation: EmberGen (GPU based, non-AI but fast), future potential for AI research. Style Transfer: Runway Gen-1/ 2.
Sound Design	Manual recording and placement of sound, foley, music by a sound designer.	SFX: LALAL.AI (stem separation), SFX search sites with AI tagging, "AI SFX Generators" (emerging). Music: AIVA, Soundraw, Amper Music, Google MusicFX.
Rendering	Computation process to generate the final output, can be time-consuming.	Denoising: Nvidia OptiX (in Blender, V-Ray, Octane), Intel Open Image Denoise. Upscaling: Topaz Video AI, Topaz Gigapixel AI, Upscayl.

C. The Impact of AI on Creative Workflows and the Role of Animators

Collaboration and integration of AI devices in the animated film production workflow significantly affect the working process at each production stage [9], [12], [47]. At the pre-production stage, AI can intervene in the process of collecting ideas, scripts, character designs, background designs/environments, storyboards, and animatic storyboards. This capability allows conceptors and policymakers to explore concepts more widely in various directions and determine a focus sharply and deeply [1], [48].

At the production stage, AI can automate the keyframing, in-betweening, line cleanup, and coloring processes. The results of the automation between keyframes are smooth movements [6], [49], [50]. Then, in the character animation process, motion capture does not simply capture raw data but processes and analyzes the results to display realistic and meaningful movements [51]. Likewise, the depth of emotion is displayed through facial expressions [52], [53]. To support the creation of textures and background illustrations, AI can help produce textures and backgrounds with good and varied details in a short time [54], [55], [56].

At the post-production stage, tasks from compositing to editing become more consistent with AI support [12], [13], [57]. In addition, optimizing the rendering process by improving the quality of lighting, textures, and shadows can significantly reduce the time required to produce high-quality visual works [58], [59]. The role of animators hasve shifted slightly with AI's involvement in the animated film production process. AI can be relied on to handle repetitive, time-consuming, wordy, and energy-consuming tasks. So that animators can pay more attention to creative concepts and the refinement of the work produced by AI. Thus, concerns about potential job losses can be refuted if animators can improve their skills in maximizing the benefits of AI. Animators who can adapt are necessary to survive and be relevant in the animation industry, which is increasingly dependent on AI [1], [5], [6], [12], [60].

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D. A Successful Human-AI Collaboration Case Study in Animation

At least two animated films have successfully integrated AI into their workflow. This shows the success and benefits of human collaboration with AI in the animation industry. First, Disney's Frozen II, which was released in 2019. Disney developed an AI-based physics simulation system called "Swoop". Swoop is able to generate realistic natural elements, such as snow, water, and ice, with various movements and changes in the form of these natural substances [9], [61], [62]. Then Disney introduced "Hyperion", which is a streaming ray-tracer. Then Disney introduced "Hyperion," a streaming ray-tracer—a machine learning-based lighting system to speed up the rendering process [63]. The refinement of the character's facial expressions in displaying emotions and synchronous lip movements is also inseparable from the support of AI [9].

Second, the hybrid live-action animated film The Lion King, which was also released in 2019. In this film, AI was used to explore the natural movements of the face. In order to maintain the characteristics of each animal shown, body movements and facial expressions were made so that they still displayed the natural movements of animals that are alive and appropriate. To create realistic animation in a crowd, Disney's CGI department then developed a special program so that the animals would not collide with each other when running in a herd. These examples above show that the collaboration between human animators and AI can produce visually stunning animated films [64].

E. Challenges and Opportunities Arising from AI Integration

Integrating AI in animated film production has a significant impact and can be considered both an opportunity and a challenge. From an economic perspective, AI has the potential to lower production costs and increase production efficiency through the conventional automation of repetitive and time-consuming tasks. However, this efficiency will impact concerns about labor market displacement. Animators who cannot adapt to these new skills will undoubtedly be displaced [6], [65], [66], [67].

From an artistic perspective, AI offers opportunities that humans have never had regarding creative diversity. AI's ability to innovate, provide new styles, and develop narratives with a broad knowledge base cannot be matched by humans. AI can help artists overcome creative deadlocks [60], [68], [69], [70].

F. Ethical Perspective

From an ethical perspective, there are many conflicting views regarding artistic integrity, originality, copyright, data privacy, and the potential for bias in algorithms and works produced by AI. It is essential to ensure that the use of AI is in accordance with human integrity and maintains ethics [71].

Automation systems in animation production are increasingly developing. There are concerns that the role of humans will be displaced in various stages of the creative process. This requires open discussion of clear policies from stakeholders so that AI remains within the corridor, which values human contributions and ensures the sustainability of the animator profession and the creative work ecosystem. It should be emphasized that humans can only do several aspects of the creative process. Unique human competencies that AI systems cannot replace include: understanding cultural context, emotional experience, local values, and the ability to empathize with characters and audiences [72], [73].

Consciously, the presence of AI can be a tool to strengthen the role of (human) creators in expressing their uniqueness and originality. Thus, transparency in the use of data, protection of intellectual property rights, and respect for the authenticity of human expression are the main principles in building a future that is fair, sustainable, and meaningful for collaboration between humans and artificial intelligence [74].

G. Strategies for Integrating Artistic Vision with Generative AI Capabilities

Creators are expected to be able to effectively and efficiently combine their artistic vision with the power of generative AI. The approach used is AI as a collaborative tool, not as a substitute for human creativity. As mentioned above, animators can maximize the use of AI to automate repetitive and time-consuming tasks. Artists can use AI

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tools to find inspiration for new styles, textures, and characters that may never have been considered and presented through conventional processes [65], [66], [67].

It is essential for animators now to learn new skills in using AI tools and develop those skills. Through mastery of these tools, animators are expected to be able to maintain creative control and ensure that the work produced by AI is in line with their vision. Humans remain in control of monitoring and refining the work produced by AI [68], [69], [70].

H. The Balance between Human Creativity and Technological Innovation

While AI offers unprecedented efficiency and creativity, the touch of human knowledge and intuition remains irreplaceable. The animation industry must avoid over-reliance on AI. The animation industry must avoid over-reliance on AI, as dependence on it can create a homogenous animation style, suppressing human creativity. Therefore, the balance between human creativity and the use of technological innovation is essential in the animation field [66], [67], [70].

The development and acceleration of AI capabilities are inevitable and cannot be denied. AI developers are competing to improve the intelligence and abilities of their creations [75]. Like it or not, the future of animation lies in collaboration, where humans and AI combine forces to create animated films that are innovative, inspiring, and resonant. AI can help animators complete repetitive and tedious tasks, increase the realism of their work, and speed up production times. Meanwhile, humans can inject emotions, personalities, and unique creative insights. This unique balance ensures that AI is positioned as a supporter of increasing human creativity and value, rather than taking over the role of humans [3], [21], [76]. From the eight points of presentation above, Table IV will show a comparison of the capabilities of AI tools with humans/animators, which shows the gap between the two.

As seen in the comparison table, the first column shows tasks that can now be fully done by AI through automation. The second column shows areas where AI tools and humans can work together. AI tools serve as aids to accelerate and enrich the creative process. As a note, supervision and final decisions must still be made by humans. Finally, the third column shows that creativity, artistic intuition, ethical judgment, and artistic vision still depend on human capabilities and cannot be replaced by AI tools.

TABLE IV
Comparison of The Capabilities of AI Tools with Humans/Animators

Jobs That Can Be Done by AI Tools	**Jobs That Can Be Done by AI Tools and Humans**	**Jobs That Can Only Be Done by Humans**
- In-betweening automation (filling frames between keyframes). - Rendering and optimization of lighting, textures, and shadows. - Physics simulation for water, fire, smoke, and cloth effects. - Automatic asset creation (background, texture, HDRI). - Prediction and correction of motion capture data. - Concept art creation based on text input (diffusion model).	- Development of story concepts and creative ideas. - Storyboard creation based on scripts. - Editing and revising animation results based on feedback. - Arranging visual composition and aesthetics. - Collaboration in the creative process between various production departments.	- Determining artistic vision and emotional value in the work. - Intuitively conveying meaningful and cultural messages. - Ensuring originality and artistic integrity. - Critical and ethical assessment of the use of technology. - Complex creative decision making and adaptation to new situations.

IV. CONCLUSION

The future of the animation industry will likely involve AI more deeply. The future advances that are starting to be enjoyed today lead to various forms of creative expression, personalized content, and collaborative workflows. AI is positioned as an innovative partner that can help the brainstorming process refine ideas.

This transformation is faced with massive challenges. The role of conventional animators will shift; animators must adapt and develop new skills to survive. These new skills focus on

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describing "creative", curating AI works, and determining the tolerance level for human collaboration with AI.

Ethical concerns, such as copyright, artistic originality, and the potential for job market disruption, will be crucial and require ongoing attention to be discussed and agreed upon with policymakers in the industry sector involving AI.

The success of adopting AI technology in animation depends heavily on the ability of the industry and the parties involved in it to achieve the right balance. The future of AI-powered animation is about collaboration, where technology empowers human creativity to reach new levels.

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