Modern technologies for digital animation study programs

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Abstract: *The article addresses the issue of initial training for specialists in the field of digital animation from the perspective of leveraging the latest informational technologies, including those based on Artificial Intelligence, augmented reality, virtual reality, mixed reality, and extended reality. It examines 10 university educational programs and over 120 software tools useful for digital animation, which allowed for the synthesis of the main professional competencies of digital animators and the most effective digital animation software capable of assisting in the development and enhancement of these competencies.*

Keywords: Digital animation, Educational program, Software, Skills, Competences.

1. Introduction

The animation industry is in a state of continuous growth, and its impact is felt across various fields of human activity. The demand for animation specialists has increased significantly. As a result, universities have developed various educational programs in the field of animation. Programs focused on traditional animation (through hand-drawing) concentrate on developing drawing skills, acquiring knowledge in color theory, human anatomy, scriptwriting, and traditional animation production. Programs oriented towards digital animation focus on utilizing informational technologies to create high-quality animations. These include 2D and 3D animation techniques, producing special digital effects, virtual and augmented reality applications, as well as other advanced technologies.

For the effective training of future specialists in digital animation, it is important that educational programs be dynamic and keep pace with new informational technologies, so as to leverage artificial intelligence (AI), virtual reality (VR), augmented reality (AR), mixed reality (MR), extended reality (XR), etc.

In this regard, we will conduct an analysis of the components that shape specialists in the field of digital animation with the aim of identifying trends, perspectives, challenges, issues, and software solutions conducive to education in digital animation.

2. Methodology

To achieve the mentioned goal, the following aspects influencing the training of specialists in digital animation were investigated:

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a) The process of designing and producing digital animation was analyzed from the perspective of leveraging the latest informational technologies.

b) The curricula of animation programs from 10 universities in the USA, Europe, and Asia were studied.

c) In accordance with the stages of creating digital animation, a total of over 120 software tools were analyzed.

d) As a result, the profile of the digital animator was studied, which was important for synthesizing their main professional competencies and identifying the most effective software capable of assisting in the formation and development of these competencies.

3. Analysis of the process of designing and producing multimedia products

The animation production process encompasses several directions:

a) **Two-Dimensional animation (2D)** is characterized by the representation of objects and characters in a two-dimensional space. Traditionally, since the 1800s, 2D animation was produced primarily through hand-drawing, specifically through the layering of frames, where drawings follow one after another, each slightly different from the previous one. Each second comprised 24 frames. With the development of informational technologies, the process of creating 2D animation has been digitalized, making it possible to draw and animate characters and backgrounds directly on the computer (Zheng, 2021).

b) **Three-Dimensional animation (3D)**, also known as 3D animation, is part of the new generation of animations that emerged with the continuous development of informational technologies. It is one of the most popular types of animation and is widely used in film production, video games, advertisements, and more. 3D animation involves placing and manipulating characters and objects in a three-dimensional space to create the illusion of movement. Objects are created based on 3D models, integrated into a digital environment using 3D modeling tools, or by scanning real objects and transferring them into the computer as a basis for animated 3D objects (Yan, Xin & Zhang, 2023).

c) **Production of digital special effects** in animation involves using technologies and software to create visual elements that can transform and enhance the appearance and impact of an animation. These effects can range from shading and lighting to complex details such as visual distortions, fluid motions, and more (Qian, 2022).

d) **Production Based on Augmented Reality (AR)** is a technology that extends the physical world by overlaying digital information such as sounds, videos, and graphics. There are four types of augmented reality: 1) ***Marker-Based***: Requires a specific template, called a marker (e.g., a QR code), over which a

virtual object is superimposed; 2) ***Markerless***: Does not require a marker. Instead, a network is overlaid on the environment, and key points are detected to anchor the virtual model; 3) ***Projection-Based***: Uses a projector to create a digital layer on nearly any surface, eliminating the need for paper instructions; 4) ***Superimposition-Based***: Partially or completely replaces the original representation of an object with an augmented representation of the same object (Wang & Cai, 2024).

e) **Production Based on Virtual Reality (VR)** is a computer-generated simulation of an alternate reality. There are four types of virtual reality: 1) ***Standalone VR***: Operates independently without needing additional external equipment (e.g., computer or console), such as the Oculus Quest. It requires only the VR headset and controllers; 2) ***PC-Based VR***: Uses VR headsets that require a constant connection to a computer, such as Oculus Rift S for PC, Valve Index, HTC Vive, Pimax, and Windows Mixed Reality. 3) ***Console-Based VR***: Refers to VR systems like PlayStation VR for PlayStation; 4) ***Web-Based VR (WebGL)***: An API for 3D graphics in web browsers, part of HTML5 and the browser's Document Object Model (DOM API). It can be used with programming languages that support DOM API, such as JavaScript, Rust, Java, and Kotlin.

VR involves motion tracking using VR equipment such as headsets, gloves, and vests. There are two main types of motion tracking in VR: 1) ***Inside-Out Tracking***: Uses cameras integrated into the VR headset to monitor the environment and the position of the headset and controllers in real-time. Examples include Oculus Rift S, HTC Vive Cosmos, and most Windows Mixed Reality headsets; 2) ***Outside-In Tracking***: Involves placing base stations or sensors in the corners of a room or surrounding space. These bases actively track the position of the VR headset and controllers, generating a movement map. This system offers greater accuracy and can support more complex movements. Examples include HTC Vive Cosmos Elite and Valve Index.

e) Production of AI-Generated Content (AIGC) is the creation of AI-generated content (AIGC), which includes generating 3D models from texts, images, or videos. These generators are useful for various applications, such as creating models for 3D printing or developing 3D representations of objects that do not exist in the real world.

There are three types of AI generators for transformation: 1) ***Console-Based VR***: Refers to VR systems like PlayStation VR for PlayStation 4; 2) ***Text to 3D Models***: Converts textual descriptions into 3D models; 3) ***2D Images to 3D Images***: Transforms 2D images into 3D representations; 4) ***Videos to 3D Objects:*** Converts video content into 3D objects (Yuanliang & Zhao, 2024).

In general, the process of creating animations includes 3 main stages: pre-production, production and post-production.

3.1 Pre-production

Pre-production is the first stage in animation creation. In this stage, the animation team develops the story, writes the animation script, designs the characters, creates the storyboard (visual representation of the script), chooses the color palette, prepares the backgrounds, and records the dialogues between characters. It is a preparatory stage that precedes the actual production process. A well-written script should include all character actions and the storyline. The pre-production stage is divided into five components: a) **Idea Generation**: Every story begins with an idea. Ideas for animation are discussed by copywriters, screen-writers, and directors; b) **Script Creation**: Ideas are developed and refined until a cohesive picture is formed. The script represents the narrative and literary form of the story, including character movements, the environment, chronology, actions, and dialogues; c) **Storyboard**: This is a visual representation of the script. Each image in a storyboard visually describes a stage in the story or a moment in the script; c) **Animatic**: This is the moving form of the storyboard; d) **Visual Concept of the Project**: At this stage, the final design of the project is established, including conceptual design, character sketches, costume designs, and background setup.

3.2 Production

Production is the process of creating the animation by combining all materials and developing the scenes. It involves next steps: a) **Modeling**: Create 3D objects using computer models. Simple 3D models are shaped by meshes of points, lines, and curves, and are textured and colored to look realistic; b) **Texturing**: Apply textures to 3D models to represent materials like metal or wood, giving them detailed surface appearances; c) **Rigging**: Create a skeleton for characters to enable movement. Attach the 3D model (skin) to this skeleton for animation; d) **3D Animation**: Place characters into scenes and animate them using keyframes for starting and ending positions of movements; e) **Lighting**: Set up the angle and depth of light in the scene to enhance the visual effects, based on pre-production materials; f) **Rendering**: Convert 3D models, textures, and animations into 2D images or video clips. This stage involves detailed calculations for lighting, shadows, and colors, and can be time-consuming.

3.3 Post-production

Post-production is the final stage of editing the animation. During this phase, the animation is enhanced with additional sound effects or background music to amplify its emotional impact. Once the final version is ready, it is rendered and exported in various formats. Post-production involves final detailing and adding finishing touches, giving the project its final appearance. It includes the following components: a) **Compositing**: To achieve the final result, previously visualized layers are recombined in the compositing process. This can be very complex, as animation may involve hundreds of different layers; b) **2D Visual**

Effects: Some visual effects, such as sparks, dust, raindrops, or camera shake, are easier to create in 2D at the end of the project without affecting quality. These effects are usually blended with other layers during compositing; c) **Color Correction**: Also known as color grading, this is the final adjustment made to the 3D animation. This step ensures that each frame and the entire project are consistent and cohesive; d) **Video and Sound Editing**: In this stage, video editing is performed, titles are added to the video sequence, and any necessary effects for the final video and text are applied. Audio recordings and dialogues are also edited, ensuring lip-sync and the addition of necessary sound effects for the video.

4. Market analysis of digital animation software

4.1 2D Animation softwares

2D Animation softwares provides different aspects of 2D animation, from intricate drawing and special effects to comprehensive libraries and high-resolution output.

Table 1. 2D Animation creation applications

No.	**Name**	**Sistem Supported Operating System**	**Price**
1.	Toon Boom Harmony	Windows, Linux, macOS	109 $ / month
2.	Moho	Windows, macOS	399.99 $/licence
3.	Adobe Animate	Windows, macOS	20,99 $ / month
4.	OpenToonz	Windows, macOS	Free
5.	Synfig	Windows, Linux, macOS	Free
6.	Pencil 2D	Windows, Linux, macOS	Free
7.	Maefloresta	iPhone, Android	Free
8.	Stop Motion Studio	Windows, macOS	59.99 $/licence
9.	FlipBook	Windows, macOS	19.99 $/licence

Toon Boom Harmony 21: Professional 2D animation software used by major studios like Disney and DreamWorks. It works on Windows and macOS, offering features such as extensive brush options, special effects, layer management, particle representation, and 3D transformation of 2D objects. It includes a texture and template library.

Moho: A professional 2D animation program that supports drawing on graphic tablets, frame creation, and layer processing. It features a built-in library of objects and characters, Unity compatibility, scene import/export, background addition, and audio overlay. It also has technology for creating realistic skeletons.

Adobe Animate: Formerly Adobe Flash, this 2D animation software allows for traditional, vector, and interactive animations. It supports up to 4K resolution,

detailed frame rate adjustment, and multiple file formats including SWF, HTML5, and video. It also offers advanced interactive design features.

OpenToonz: An open-source 2D animation software developed by Studio Ghibli, supporting both traditional and digital animation. It provides various animation tools, imports/exports multiple formats, and is available for free on Windows, macOS, and Linux for both commercial and non-commercial use.

4.2 3D Animation softwares

These programs offer 3D modeling and animation capabilities, including polygonal modeling, material editing, lighting setup, and animation production. They also support the import of various models and materials.

Table 2. 3D Animation software applications

No.	**Name**	**Sistem Supported Operating System**	**Price**
1.	Autodesk Maya	Windows, Linux, macOS	1785 $/year
2.	3ds Max	Windows	1545 $/year
3.	Cinema 4D	Windows, macOS	59.10 $/year
4.	Blender	Windows, Linux, macOS	Free
5.	LightWave 3D	Windows, macOS	995 $/year
6.	FreeCAD	Windows, Linux, macOS	Free
7.	3D Builder	Windows	Free
8.	Houdini	Windows, Linux	269 $/year
9.	ZBrush	Windows, macOS	39,95 $/month
10.	Daz 3D Studio	Windows, macOS	Free
11.	SketchUp	web browser	Free

Autodesk Maya: A professional 3D animation and modeling software widely used in video game development and film production. Compatible with Windows, Linux, and macOS, it offers advanced tools for animation, scene creation, lighting, and textures. Integrates smoothly with Adobe After Effects.

3ds Max: Developed by Autodesk, it is suitable for film, TV, games, and architecture. It provides a range of tools for fluid motion, collision effects, gravity, and detailed modeling of surfaces and visual effects.

Cinema 4D: A professional application for 3D animation and 2D graphics, featuring tools for realistic modeling and rendering. It can be extended with modules for scene visualization and motion simulation. Noted for its user-friendly interface but comes with a high license cost.

Blender: A free, open-source program for 3D and 2D animation that covers all stages of creation, from modeling to video editing. It supports advanced functions such as image synchronization with background soundtracks.

4.3 Digital Effects Production Softwares

Digital Effects Production Softwares presents a range of tools and features designed to create and enhance visual effects in animations and films.

Table 3. Special effects production software for animation

No.	**Name**	**Sistem Supported Operating System**	**Price**
1.	Adobe After Effects	Windows, Linux, macOS	Free
2.	Particle Illusion	Windows, macOS	Free
3.	Nuke	Windows, Linux, macOS	528 $/year
4.	Wondershare Filmora	Windows, macOS	Free
5.	Fusion	Windows, Linux, macOS	299 $/year

Adobe After Effects: A powerful tool by Adobe for creating 2D and 3D animations, complex visual effects, and video editing. It is ideal for designing animated interfaces, infographics, dynamic titles, logos, and transitions. It features pre-defined templates and keyframe animation, making it popular for commercials, music videos, and film production.

Particle Illusion: A specialized tool for creating and animating particle effects such as smoke, sparks, and explosions.

Nuke: A high-quality compositing and visual effects software used for integrating and manipulating visual elements within scenes or sequences.

4.4 Software for Augmented and Virtual Reality

Table 4. Augmented and Virtual Reality production software

No.	**Name**	**Sistem Supported Operating System**	**Price**
1.	Unity	Windows, macOS	Free
2.	Unreal Engine	Windows, macOS	Free
3.	ARKit	iPhone și iPad	Free
4.	ARCore	iOS 11, Android, Unity, Unreal Engine	Free
5.	Vuforia	Android, iOS, Unity, Windows	Free
6.	ImagineAR	iOS, Android	Free
7.	Lens Studio	Windows, macOS	Free
8.	Wikitude	iOS, Android, Windows	559 $

To create an augmented reality application, you need a Software Development Kit (SDK) integrated with Unity and Unreal Engine:

Unity: A cross-platform game engine used for 2D and 3D game development.

Unreal Engine: A professional game engine primarily used for 3D games and virtual reality applications. Both engines offer powerful features and flexible scalability to meet various game development needs.

ARKit (for iPhone and iPad) offers: reliable facial tracking, environmental light estimation and 2D object detection (horizontal, vertical, angled surfaces).

ARCore (for Android) provides: detection of flat and inclined surfaces, automatic light adjustment and anchoring virtual objects to physical objects maintaining position even if the camera moves away and returns.

Vuforia offers advanced features including text and visual object recognition, support for both marker-based and markerless AR, 3D environment scanning, multiple object detection, and a Simulation Play mode for analyzing 3D models.

EasyAR features real-time 3D environment scanning and network generation, compatibility with unsupported Android smartphones, 3D object tracking, real-time 2D image recognition and tracking, and screen recording.

Lens Studio offers tracking of the face, neck, elbows, and hands, hair color changes and face mask applications, and 3D model creation.

4.5. Artificial Intelligence (AI) tools for digital animation

There are three types of AI generators:

a) Text-to-3D Generators:

Spline AI: An AI tool that converts text descriptions into realistic 3D models and animations. For example, inputting “red car with three doors” results in a 3D model of the described car.

Masterpiece Studio: The first AI generator that uses Natural Language Processing to transform text into 3D models. Typing “violin” produces a detailed 3D model of a violin.

Meshcapade: A platform that creates accurate 3D avatars and digital doubles from any data source, even from single images.

b) 2D-to-3D Image Generators:

NeROIC: Converts 2D images into 3D models and creates 3D scenes from video clips, allowing for customizable 3D content.

DPT Depth Estimation: Uses neural networks to generate 3D point clouds from single images, effective in complex scenes and lighting conditions.

RODIN: AI system that creates detailed avatars from personal data, with customizable attributes like gender and age through natural language.

c) Video-to-3D Generators:

Move.AI: Converts video footage into 3D models using AI, capturing precise human motions with modern cameras.

Rokoko: AI tool for transforming video motion into 3D, offering features

like foot locking and slip editing for accurate capture.

DeepMotion: Top AI generator for real-time 3D body tracking and animation, enabling quick creation of complex character animations without specialized gear.

Table 5. AI-generated content production applications

No.	**Name**	**Sistem Supported Operating System**	**Price**
1.	Spline AI	web browser	Free
2.	Masterpiece Studio	web browser	Free
3.	Meshcapade	web browser	Free
4.	NeROIC	web browser	Free
5.	DPT Depth Estimation	web browser	Free
6.	RODIN	web browser	Free
7.	Move.AI	web browser	Free
8.	Rokoko	web browser	Free
9.	DeepMotion	web browser	Free

5. Skills of a digital animator

Until recently, working in the animation field did not require specialized training. Many individuals entered the industry after completing studies in a more general artistic field. While general academic preparation can be valuable, skills and experience are the actual deciding factors for employment. An animator must demonstrate a broad range of skills, including artistic abilities, software management, and interpersonal skills. Animators develop these skills through education and professional experience, continuously improving them throughout their careers.

Table 6. Professional skills of a digital animator

Categories of Competencies	**Fields**	**Competencies**
Artistic Skills	• Color Theory • Design Principles • Drawing and Composition • Storyboarding • Media Theory • Visual Language	• The ability to combine colors, understand how colors interact and blend with each other. • Knowledge and application of graphic design principles (balance, hierarchy, alignment, repetition, contrast, and others). • The ability to create characters, backgrounds, and objects that bring stories to life. • The ability to visualize and organize the story before production. • Understanding how media content

		influences and is influenced by society, culture, and technology, and creating effective and relevant media content. • The ability to use visual elements to communicate ideas, information, or emotions effectively.
Software Proficiency	• Spatial rendering • Visual effects • Game design • Fundamentals of animation • Computer generation programs • Motion capture software • Rigging	• Ability to create 3D visuals with accurate depth and perspective. • Knowledge of applying techniques to enhance imagery with dynamic elements. • Capacity for designing engaging rules, content, and mechanics for video games. • Understanding of basic principles to create smooth and realistic animations. • Proficiency in using software to develop digital 3D models and animations. • Skills in using tools to record and animate human movement. • Expertise in creating digital skeletons to facilitate the animation of 3D models.
Interpersonal Skills	• Communication • Problem-Solving • Flexibility • Time Management • Prioritization • Self-Discipline	• The ability to collaborate with other artists, directors, and team members, and to express creative ideas effectively. • The ability to solve technical problems and find creative solutions to animation challenges. • The ability of adapting to changes and new situations with ease. • The ability to manage multiple tasks and meet deadlines in a dynamic environment. • Assessing tasks to focus on the most important ones first. • The willingness to learn new tools and techniques and adapt to different animation styles or project requirements.

Given that the profession of animator has become increasingly sought after, specialized education has become the preferred choice for many educational institutions worldwide. Training for animation specialists is available in various forms, ranging from initial training and traditional academic programs (certificates, diplomas, bachelor's, and master's degrees) to specialized courses for professionals, offered by both public and private institutions.

The following diagram illustrates the correspondence between digital animator’s competencies and digital animation software.

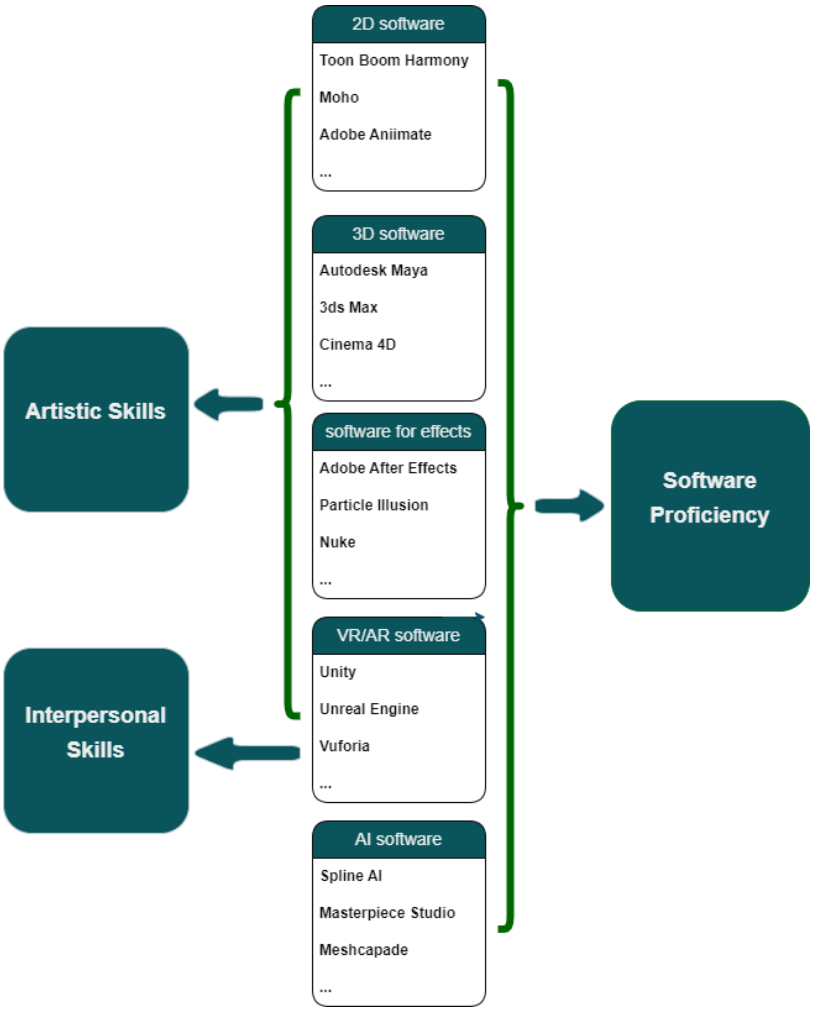

Diagram 1. The correspondence between digital animators' competencies and digital animation software

6. Comparative analysis of study programs for digital animation

As the digital animation industry continues to evolve and job opportunities in this field expand, the number of universities offering specialized programs in digital animation has also increased. These educational programs train professionals in various roles such as designers, engineers, and programmers for complex productions in advertising, electronic media, film, digital production, game design, and more. The courses within these programs are diverse, covering both the stages of creating digital animation products and the philosophy of digital art.

Table 7 presents the courses offered by 10 universities that specialize in digital animation: **University of Malta** - *"Art in* Graphic, *Design, and Animation"*;

Academy of Art University, San Francisco - *"Animation and Visual Effects"*; **California Institute of the Arts (CalArts)** - *"CalArts"* ; **Tokyo University of the Arts** - *"Animation"* ; **University of the Arts London** - *"Computer Animation and Visual Effects"*; **University of Cambridge** - *"Animation and Illustration"*; **OCAD University, Toronto** - *"Experimental Animation Arts"*; **WSB University, Poland** - *"Experimental Animation"*; **Communication University of China** - *"Art of Animation"*; **Ion Creangă State Pedagogical University, Chișinău** - *"Animation"*.

Table 7. Comparative analysis of animation study programs

	U1	**U2**	**U3**	**U4**	**U5**	**U6**	**U7**	**U8**	**U9**	**U10**
Introduction to Visual Design										
Tools for Digital Art										
Design and Modeling										
2D Animation										
3D Character Animation										
Graphic Design										
Introduction to Computer Graphics for Animation										
Kinematics for Animation and Visual Effects										
Introduction to Animation Principles and Techniques										
Scriptwriting										
Post-production										
History of Animation										
Traditional Animation										
Introduction to Rigging										
Human Anatomy										
Color Theory										
Design Thinking										
Sound Design										
Research in Animation										
Painting										

7. Conclusions

The comparative analysis of the study programs from the ten universities that train specialists in digital animation reveals key courses designed for the professional preparation of digital animators. These include: fundamentals of animation (or other courses covering the principles and stages of digital animation creation), digital animation tools, animation design, script creation, 2D animation production, 3D animation production, digital effects production, and other complementary courses specific to the university's chosen focus.

In the context of new technologies such as AI, AR, and VR, the emergence of new university courses or modules within existing courses is anticipated. These will develop skills for utilizing these technologies in digital animation production.

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