THE ANNALS OF "DUNAREA DE JOS" UNIVERSITY OF GALATI
FASCICLE IX. METALLURGY AND MATERIALS SCIENCE
N°. 3 - 2024, ISSN 2668-4748; e-ISSN 2668-4756
Article DOI: https://doi.org/10.35219/mms.2024.3.06

ADVANCED MODELING AND 3D PRINTING TECHNIQUES FOR GAME AND CGI CHARACTERS

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ABSTRACT

This article explores the methods of designing 3D elements used in video games and CGI, highlighting the impact of these techniques on the perception and experience of digital art. 3D models are fundamental to create immersive virtual worlds, and the 3D modeling process extends from conception to execution, combining engineering principles with industrial design. Advanced three-dimensional modeling software such as Blender or Adobe Substance 3D Painter are built to create realistic models, while additive manufacturing with SLA technology allows rapid prototype development of game characters. The article also discusses the interoperability between certain three–dimensional modeling platforms on the current market and the impact of new technologies such as the so-called digital twins or the metaverse, on the future of three-dimensional graphics and three-dimensional modeling of game characters. Through these technological advances, 3D modeling is redefining the boundaries of design, offering limitless opportunities for innovation in the gaming industry.

KEYWORDS: game characters, CGI, additive manufacturing, SLA

1. Introduction

The design methods for 3D elements used in video games and CGI have radically transformed how we envision and experience digital art, bringing creativity into previously unexplored territories. 3D models represent the visual backbone for most video games and CGI content, essential not only in film but also across many visual media. These models are fundamental in constructing captivating and highly realistic virtual worlds, with lifelike characters and settings that interact naturally with their environment. The goal of 3D modeling in this context is to give a sense of realism and immersion, offering viewers and players an intense "lost and found" experience within the fictional world created.

The flexibility in customizing and varying 3D models allows creators to quickly transform basic models into complex objects and characters, adjusting features to build a unique, rich, and dynamic world. Thus, introduces a sense of novelty and surprise, essential for an engaging experience. The unlimited possibilities of 3D modeling appear in a wide range of projects: from creating futuristic, lifelike characters in video games to highly detailed objects used in film and advertising. In such projects, the 3D modeling process becomes a flexible creative tool that can be adjusted and optimized to meet project needs without compromising the product's final purpose.

To create a 3D model for a mecha-type character, the process begins with fundamental research and the development of a visual concept [1]. This is followed by the actual modeling of the distinctive and complex elements of such a robot character, rendering, and integrating the finalized model into its intended use scenario, whether in films, games, or other platforms. The purpose of this work is to detail the complete process from concept to execution, highlighting how engineering and industrial design principles combine to create realistic and functional mechanical structures. Furthermore, this approach highlights methods for joining mechanical parts, texturing, and the application of light and shadow to render materials (metal, leather, plastic) characteristic of a mecha.

Three–dimensional design and modeling are now simplified and accessible thanks to advanced

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software, enabling designers to preview and manipulate models from any angle, in detailed and intuitive ways. This technology removes the need for costly physical prototypes and enables quick testing and modification at each design stage. Thus, 3D modeling not only reduces production costs and time but also improves team collaboration by providing a clear and precise visual representation of concepts.

Another important aspect is interoperability among different 3D modeling software platforms, such as Blender, AutoCAD, or Maya. Commonly used 3D file formats like FBX, OBJ, or gLTF/GLB facilitate data exchange and ensure compatibility across software applications. Choosing the right format is essential to avoid data loss or compatibility issues in the design process. Modern software allows exporting and converting between different formats, ensuring that 3D models can be adapted and reused in various contexts and platforms, from augmented and virtual reality simulations to film and gaming industries.

Nowadays, the future of 3D modeling, emerging technologies like digital twins [2] and the metaverse [3] offer new opportunities to connect physical and virtual reality. For instance, digital twins enable real-time monitoring of physical entities through virtual replicas, useful in engineering, medicine, or complex simulations. Similarly, the metaverse concept, a collective digital space, allows the use of 3D objects and avatars for social interactions and immersive virtual experiences.

Through the continuous evolution of 3D modeling software, economic benefits, increased efficiency, customization capacity, and precision of detail are fundamental reasons for the popularity of these technologies.

Over time, the development of video games has evolved significantly, allowing 3D modelers to create immersive and highly realistic experiences for players. From 2D effect, games have progressed to 3D effect, offering vibrant scenes like those in movies. 3D artists develop animated textures and plan the design of each model to ensure the quality and performance of the game. Thus, the 3D video game industry has established itself as a representative of cutting–edge technology in entertainment, and 3D games are gradually becoming an important part of everyday life. 3D models are created using specialized software, which enables the generation of environments, characters, and other visible objects in games. Textures and animations are integrated to enhance the realism [4], and the models are then introduced into the game engine to create the final product.

3D technology can be divided into three main categories: 2D games, 3D games, and pseudo-3D games (or 2.5D), each with specific characteristics. In 2D games, graphic elements are composed of unique maps, while 3D games use geometric polygons to provide a more realistic gameplay screen. Pseudo-3D games combine the two techniques to meet the diverse needs of players, 3D technology brings stereoscopic visual perception, creating three−dimensional coordinates that generate a distinct virtual space.

3D technology manifests through four essential aspects in games: character modeling, scenario modeling, particle systems, and the 3D engine. Character modeling refers to the creation of virtual characters, adding living objects in the environment. This includes researching movements and facial expressions, contributing to a more engaging gameplay experience. Scenario modeling deals with generating virtual environments, integrating computer graphics, artificial intelligence, and sensor technology to create interactive experiences.

The particle system is responsible for generating special effects, such as glowing light or flames, which enhance the visual appeal of the game and attract players' attention. The 3D engine, on the other hand, is the piece that controls all these elements, abstracting materials into polygons or curves and generating final images through complex algorithms.

The game engine is essential for the development and operation of video games. It includes a complex composition made up of components such as rendering, scene structure, movement system, and collision system.

Rendering is the fundamental part that allows the display of 3D images on 2D screens, divided into software and hardware rendering. Hardware rendering is used for real−time rendering, while software rendering is primarily used for offline rendering.

The scene structure allows for the organization of 3D objects within a common space, creating a hierarchy of interconnected nodes that facilitate the management of coordinates. The movement system ensures the dynamics of the game, managing changes and movements in the 3D space through a time control program. The collision system detects interactions between objects, enhancing the game's reality by implementing surrounding structures that facilitate interaction between nodes.

Important technical aspects include polygon optimization, balance between CPU/GPU and memory, as well as level optimization. Optimization techniques aim to reduce the size of 3D model files by decreasing polygon numbers and efficiently using textures. Expert interviews highlight the importance of balancing optimization and aesthetics.

CGI (Computer Generated Imagery) is a broad term that includes 3D modeling and animation, with diverse applications in the industry, ranging from games and films to marketing and education. The

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advantage of CGI is the reuse of the 3D model, but it consumes a lot of storage space.

2. Advanced modelling process for a game character

To demonstrate the practical process of creating a 3D asset from scratch, we assembled a general step-by-step guide with the general ideas necessary for brainstorming. This case study idea and challenge was to build a fictional robot character, known in pop culture as a mecha, from the ground up. To do this, there needed to be a foundation upon which to create this mecha.

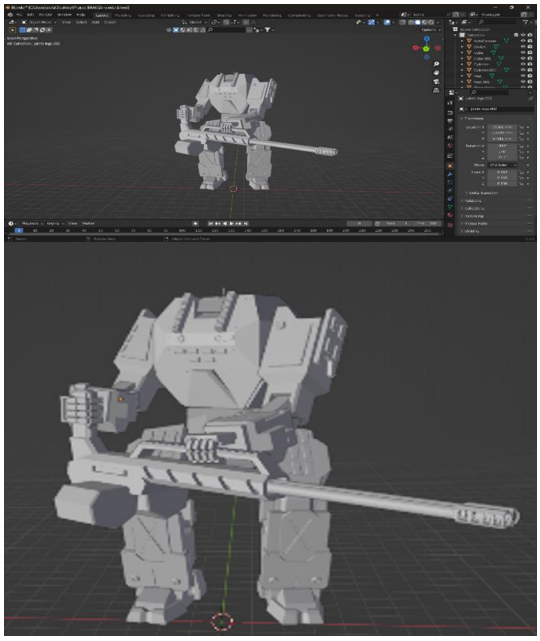

Fig. 1. *The mecha game character designed in Blender open-source software*

The first step was brainstorming some ideas, starting from the background in industrial engineering, which greatly assisted this study.

Asking ourselves, knowing that we had complete freedom regarding the size and shape and how impossible it was for it to exist, what purpose it would serve? How far into the future would exist? What size and shape would it need to have to fulfil its purpose, would it have a humanoid form, or would it reflect the technology we already have? In this study, was decided to combine all these elements into a simple description: a mecha with a heavy military unit, humanoid shape, but its mechanisms would be inspired by some real-life technologies.

Some of the real-life shape inspirations for the mecha included actual features from military vehicles. For example, as an inspiration for the torso, the cab of the Oshkosh FMTV truck was used. For the mecha head, the main source of inspiration was the M-TADS/PNVS sensor system found in the AH-64 Apache attack helicopter. The final source of general inspiration was the concept of reactive armour used on many armoured vehicles worldwide, but well represented in this image of a Bradley M2A2.

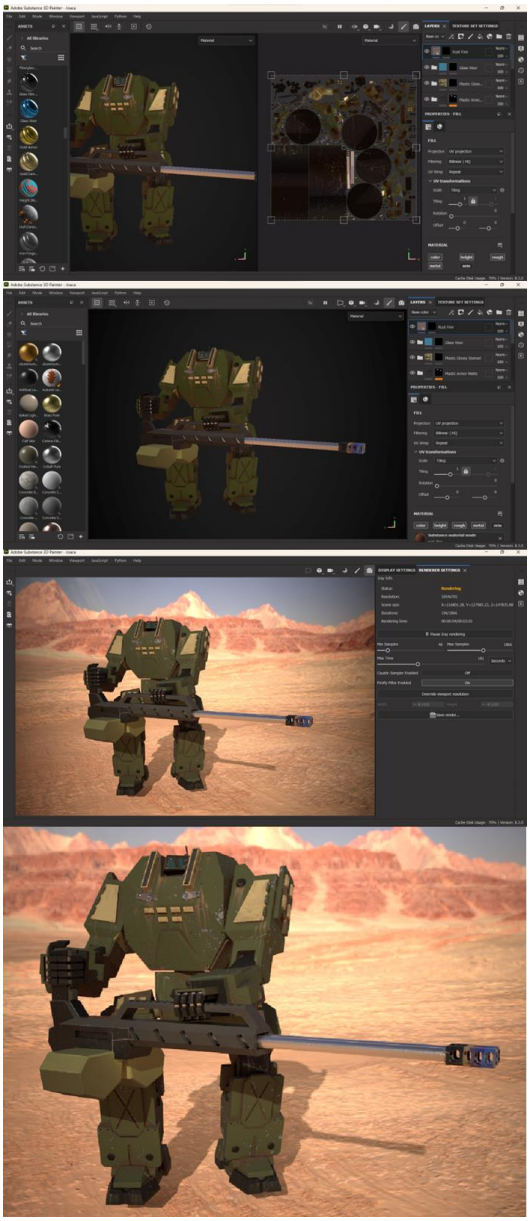

Fig. 2. *Generating textures for the video game character with Adobe Substance 3D Painter*

To simplify the 3D modeling process, isometric views of each subassembly were resorted, so that we could more accurately describe the shapes of the mecha.

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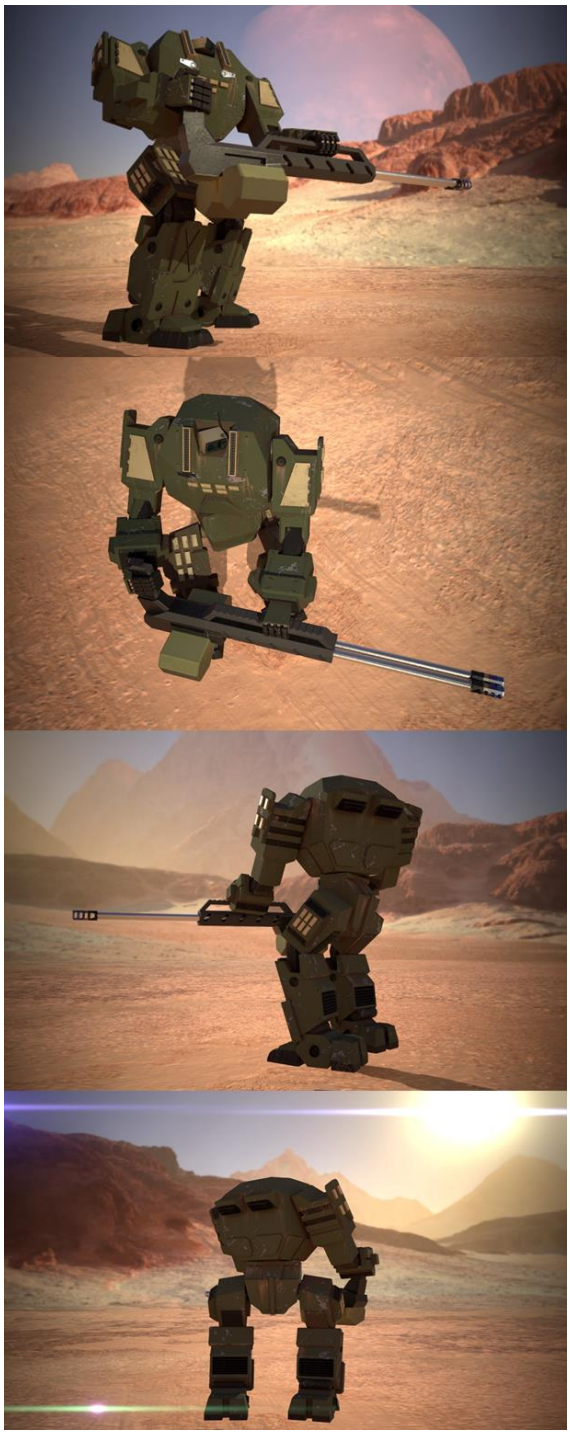

Fig. 3. *Gaming character final scenes in Substance Painter*

Creativity plays a crucial role in 3D modeling, influencing the process of creating engaging environments and characters for video games and computer graphics (CGI). Is defined as the generation and implementation of original ideas, involving innovative solutions to challenges encountered in modeling. Thus, creativity manifests through design innovation, allowing experimentation with shapes, textures, and colours to create memorable models. It also serves as a form of artistic expression, providing the freedom to communicate complex ideas and emotions, thus contributing to the construction of fantastic worlds that stimulate the audience's imagination.

Creativity is also vital to finding ingenious technical solutions, transforming limitations into opportunities, such as optimizing geometry and creating impressive visual effects. In the context of this study, the impact of creativity on the techniques and practices within the 3D modeling industry will be explored, highlighting its influence on the audience's experience.

Simultaneously, quality is a fundamental aspect of 3D modeling, having a direct impact on the difference between mediocre and remarkable creations. It refers to the extent to which a model meets established requirements, including shape accuracy, topology efficiency, textures, and overall coherence. The importance of quality in polygonal modeling is reflected in the level of detail and realism achieved, as well as the efficiency and performance of the model, which are essential for a smooth gaming experience. Well–thought–out topology facilitates the editability and manipulation of the model, offering flexibility in the processes of texturing, rigging, and animation. Thus, creativity and quality are interconnected, contributing to the success of 3D modeling process.

After, the finished surface model was exported in FBX (Filmbox) format to be imported in the texture software Substance Painter, as shown in Fig. 2 and Fig. 3.

FBX extension is an essential file format for efficiently transferring 3D models, animations and the textures between different 3D modeling software such as Blender and game engines like Unity or Unreal Engine. When developing a video game character in Blender, we can use FBX to export the complete model, including rigging (bone structure for animation) and animations, ensuring all details are preserved. This allows the character to be seamlessly integrated into video games so that it functions correctly in the game engine of choice while maintaining the desired visual quality and animations.

3. Additive manufacturing techniques for video game characters

Additive manufacturing has modeled completely the way production processes across various industries were built, and SLA, the abbreviation of stereolithography technology is known for precision and versatility, being also the oldest 3D printing

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technology. This printing technology uses the photosensitive resin as raw material, a well−known material, that facilitates the manufacturing of highly detailed objects, making it suitable for the development of prototypes and custom objects. This technology provides engineers with the freedom to generate complex forms, and very fine details, that is essential in fields such as gaming and entertainment.

SLA technology uses an ultraviolet laser to cure each liquid resin thin layers. Every 3D printing process begins with a 3D model that is sliced into thin layers in a special software generally called slicer, then the file is exported into a G-code which is transferred into the 3D printer [5]. After the printing process is started, each layer is being cured by the laser until the object is built. SLA printing offers numerous advantages: it allows the manufacturing of objects with fine details, provides design versatility, accelerates the prototyping process, and use a wide variety of materials, including transparent and flexible resins. However, there are also limitations. The higher cost of resins and the need for post–processing, such as cleaning and additional curing, are aspects that must be considered. The durability of SLA–printed objects also may be inferior to other printing methods [6].

SLA 3D printing plays an important role in the gaming industry, by developing prototypes for video games. Engineers create physical models of characters and scenarios, allowing for testing and improvement before final production. Gamers often seek custom figurines of their favourite characters, and SLA technology meets this demand by producing unique objects with a high level of detail.

A concrete example is XYZ Company, which use SLA to produce custom figurines for the game HeroQuest. The process included detailed 3D modeling, prototype testing, and the rapid production of final figures, all contributing to the fabrication of high–quality products. This technology not only facilitates rapid prototyping but also opens new horizons for creativity and innovation in this industry. Engineers can create any imaginable shape or detail without the constraints imposed by traditional methods.

In the future, SLA technology will continue to evolve, integrating artificial intelligence and machine learning, which will optimize the design and production process. The growing demand for personalized products and the need for sustainability in production will drive wider adoption of this technology in gaming and entertainment, ensuring that it remains relevant and competitive in the market.

Additive manufacturing of the game character began with the printing of components using SLA technology. This method was chosen due to its ability to produce parts with fine details and smooth surfaces, essential for a quality aesthetic appearance. A gray resin base was used, an important choice as each piece would later undergo post–processing (Fig. 4).

Fig. 4. *Components printed using SLA technology*

After the printing was complete, each component was treated with a UV curing light to ensure the necessary durability and strength. This step is vital to achieve the desired physical properties of the parts. Afterwards, layered airbrush painting was done, which allows for an even application of colour and fine detail. This technique helps create impressive visual effects, enhancing the overall look of the character and ensuring that it blends seamlessly into the gaming universe.

Fig. 5. *Components painted with different coloured layers using an airbrush*

To achieve certain details and avoid interlacing colours, paper scotch tape was used to mask the

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desired areas during painting. Later, several layers were applied with an airbrush to create shading and achieve detailed visual effects, as shown in Fig. 6.

Fig. 6. *Painting the details of the mecha game character*

Fig. 7. *Manufactured and post-processed mecha game character*

Each piece was then coated with a white paint, used as a neutral base, which allowed for an even application of the colours. Later, several layers were applied with an airbrush to create shading and achieve detailed visual effects, as shown in Fig. 5. This technique helps to improve the overall appearance of the character, ensuring that it blends seamlessly into the gaming universe.

After painting was completed, all components were assembled by soldering, ensuring that each part fits together perfectly and that the final structure is stable. This assembly stage is essential to integrate the elements and achieve a coherent and well-defined character. In Fig. 7 is shown the final SLA manufactured mecha model.

4. Conclusions

The process of designing and making 3D elements of video games and CGI has evolved significantly, redefining the way we interact with digital art. Starting the detailed modeling of characters and scenarios to their integration into graphics engines shown in this study, every step of this process involves a combination of creativity and advanced technology. Advanced modeling techniques use software such as Blender and Adobe Substance 3D Painter which provide essential tools for designers and engineers, making it easy to create realistic and captivating models. This study also shows how additive manufacturing methods allow rapid creation of prototypes and custom figures, opening new horizons in the gaming industry. New trends such as digital twins and the metaverse also promise to further transform the 3D modeling landscape, creating unique opportunities for innovation. Thus, 3D modeling continues to redefine the boundaries of design and offer immersive and captivating experiences to users, consolidating itself as an essential element of modern entertainment.

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