Process for 3D modeling and rendering optimization for low-cost music video production

Processo para modelagem 3D e otimização de renderização para produção de vídeo de música de baixo custo

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ABSTRACT  
This article presents the processes of development and production of a 3D animated music video. It mainly addresses the production processes of the piece, focusing on the efficiency of the modeling and rendering processes, aimed at authorial production on a low budget. In addition, justifying production decisions based on technical and budgetary limitations linked to 3D features and resources for producing a music video.

Keywords: computer graphics, videoclip, cost-efficient, animation, rendering.

INTRODUCTION  
The creation of music videos is an essential part of the contemporary music industry as it plays a crucial role in promoting artists and songs. However,
budget constraints often can limit the ability of independent artists and small record labels to produce high-quality music videos that capture the audience’s attention and convey the desired message.

Based on the article [1], this research aims to assess the production costs of a music video created by students in Brazil, the same location where this project was developed. It's important to highlight that the use of computer graphics allowed for a significant reduction in production costs by avoiding expenses related to lighting equipment, filming, actors, and technical staff. While [1] incurred a total cost of over $17,000.00, the only expenses covered in this project were for the computers used, which amounted to approximately $2,500.00.

In this context, the utilization of 3D modeling and rendering technologies presents substantial potential for crafting visually captivating music videos at budget-friendly expenses. However, the optimization of these processes is crucial to ensure that the results are of high quality and cost-efficient. Therefore, a comprehensive study is needed to formulate a dedicated optimization process tailored for 3D modeling and rendering within low-budget music videos.

This article aims to fill this gap by providing a solid foundation for the music industry, independent filmmakers, and video producers who seek to create visually engaging content without compromising their budgets. Finally, important aspects regarding hardware limitations and their impacts on independent production are also discussed.

Drawing from this foundation, a student project was developed with a team of two people and supervised by a professor advisor, focusing on the production of a computer graphics animated music video named "Icarus", for a local independent band. This article describes the narrative, artistic, and technical decisions made during the production of this work in order to exemplify and substantiate the recommended processes.

The primary software used for the creation of the project is Blender, a free open-source platform that encompasses all key stages of 3D production [2]. For its production, the methodology employed for modeling the project’s assets followed the guidelines outlined in [3], ranging from box modeling techniques to poly-by-poly, whereas [4] was utilized for the rendering process. Furthermore, new technologies introduced by the Blender software used in the production of
Icarus were incorporated, specifically the use of Application Programming Interfaces (APIs) between software and hardware. The API was employed to accelerate the rendering time when utilizing ray tracing, a system based on technologies found in NVIDIA's RTX graphics cards [5]. In Figure 1, a comparison can be made between the rendering of the Blender software interface used during production and the desired final rendering.

Figure 1. Comparison of interface rendering (workbench) in Blender and final scene.

2 PRE-PRODUCTION

During the pre-production phase of the work "Icarus," the steps of scriptwriting, art direction, concepts, storyboarding, and animatics were defined. The visual guidelines for the music video were divided into two main instances: the real world and the fantastical.

Initially, the character Icarus is about to perform on a stage, but his unresolved issues from the past leave him unmotivated and sad. This event provides the character with the opportunity to escape reality and journey into the
realm of fantasy. For the representation of the stage, it was decided that proportions, textures, and lighting would resemble those of real life, characterized by less saturated colors and cold lighting, aiming to emphasize the character's loneliness, as depicted in Figure 2. The predominance of gray is influenced by the protagonist's emotions, as it is commonly associated with boredom, sobriety, and dark feelings [6].

Figure 2. Color palette defined for the "Real World" of the work.

On the other hand, the second part of the narrative takes place in the fantastical environment, representing the character's subconscious. At this moment, he walks among statues symbolizing the most significant moments of his life and reflects on his journey. Finally, Icarus stands at the edge of a cliff, where he must balance his past traumas with his future prospects. In this scenario, saturated and vibrant colors dominate, accompanied by a "cartoon" texturing style, with pronounced brushstrokes on the objects in the scene, in contrast to what was seen earlier, as shown in Figure 3. The interplay between warm and cool colors also competes to achieve balance, where orange invokes controversy and the unusual, while violet represents fantasy and emotion [6].
The design of Icarus was crafted with the purpose of communicating between the two prevailing aesthetics. The character features elongated limbs to evoke a sense of strangeness and non-belonging to the real world. Similarly, the difference in rendering style between the character and the fantastical setting aims to provoke a feeling of inconclusiveness in the viewer. The neutral and less saturated color palette conceals the protagonist in the real world, emphasizing a sense of insignificance. Conversely, these same attributes make Icarus stand out when he enters the realm of fantasy, as depicted in Figure 4.

After finalizing the script and breakdown of the work, the storyboard (Figure 5) and animatic were created for the music video. These consist in simplified drawings of the overall camera placement and character's actions in
the scene. This stage's primary function was to synchronize the initial version of the produced music with the music video. Adjustments were necessary to ensure that the dramatic curve of the narrative aligned with the moments of tension in the soundtrack.

Figure 5. Frames from the storyboard created for the animation.

3 PRODUCTION

Similar to many creative processes, 3D animation begins with a simplification phase and a rudimentary concept called "blocking," which closely resembles the idea of sketching in 2D drawing. During this phase, basic shapes like cubes, circles, and spheres are employed to construct a model. In this process, only elements essential for organization and future refinement are considered, such as the character's volume, height, width, and depth. Essentially, only the fundamental forms required for the model are addressed. Subsequently, after completing the blocking phase, modifiers are typically applied to make non-destructive alterations to the existing mesh structure [3].
3.1 POLY-BY-POLY MODELING

The process known as modeling is the next stage that evolves from blocking. Modeling, whether through sculpting or shaping, involves refining the form of a subject, be it a character or a prop. There are three common methods used in 3D modeling for organic subjects: poly-by-poly (or polygonal modeling), box modeling, and sculpting. While poly-by-poly and box modeling are methods aimed at optimizing the 3D mesh for efficient subsequent processes like rigging and texturing, sculpting focuses solely on the model's shape, without considering loop organization or polygon density. Therefore, the poly-by-poly method was chosen for the execution of this project.

In poly-by-poly modeling, one of the key aspects is called “vertex loops”. As explained by [3], loops are a series of connected vertices and edges that, if we start with one vertex and follow the path down the chain, eventually return to the initial vertex.

In the example shown in Figure 7, on the left, there are highlighted loop edges that add more polygons to the mesh but are not necessary for providing detail. Hence, they can be dissolved as seen in the image on the right. Therefore, if there isn’t much detail required in neighboring face loops, they can be removed. Loops are essential in joints as they assist in rig deformation, such as in the case
of shoulders, elbows, hands, fingers, knees, and other humanoid or animal articulations.

Figure 7. Blender interface screenshot while fixing loops.

Source: Authors

3.2 CLOTHING AND ACCESSORIES

All of Icarus’ clothing items followed the same creation process, as exemplified in Figure 8. The loops from the main torso were selected, duplicated, and separated as separate objects. Then, the Solidify modifier was applied. This modifier’s function is to add depth or thickness to one or more flat faces. This process created enough thickness for the body to be covered [7].

Figure 8. Screenshot of the Blender interface during clothing production.

Source: Authors
3.3 HAIR AND PARTICLES

In order to incorporate a broader range of techniques during the modeling process, it was decided to utilize Blender's particle system for creating hair, eyebrows, and eyelashes. Particles are virtual points that respond to simulated forces or even collisions with other objects [3]. In other words, the particle system comprises virtual points that can be collectively modified. This approach did not significantly impact the character's polygonal density, which was an important consideration.

Each strand is composed of a single plane, and the "children" of these strands are duplicated. These "children" function as variations of the main hair, referred to as the emitter, and they conform to its shape and thickness while varying in size [8], as illustrated in Figure 9.

Figure 9. Screenshot of the Blender interface during hair strand creation.

Moreover, the individual strands were crafted with diverse size, rotation, and placement variations. They were subsequently arranged strategically to achieve a more lifelike appearance, as illustrated in Figure 10.

Figure 10. Screenshot of the Blender interface during hair creation.
3.4 UNWRAP AND TEXTURING

Before proceeding to the next phase, it's essential to perform polygon organization for the 3D models, a process commonly referred to as UV Unwrapping or Unwrap. Unwrapping involves the careful unfolding and optimization of texture application onto a UV Map or UV, which is also known as a polygonal mesh.

The texturing for both the character and props was carried out using two different software programs, Blender and Adobe Substance Painter, with the latter being available for free to students, thus facilitating cost-effective production. The utilization of both software applications enables a broader range of materials and textures, from highly realistic to more stylized, as demonstrated in the texture application on the character Icarus, as shown in Figure 11.

Figure 11. Preview of the character "Icarus" after applying textures.

Source: Authors

3.5 RIGGING

Starting from a textured model, the construction of a "skeleton" for the character, known as "rigging," was undertaken. Rigging involves the creation of controllers that enable articulated movement of objects [8]. Once again, a cost-effective approach was maintained through the adoption of a free platform to aid in the project. Mixamo, a website that allows for the quick rigging of imported models, was introduced into the project [9].
Icarus’s facial rig was customized using the foundation provided by the "Rigify" plugin, as shown in Figure 13, and integrated with the Mixamo plugin. This combination enabled the deformation necessary to convey movement in the eyes, mouth, eyebrows, and facial muscles, facilitating the character's expressions.

Figure 12. Screenshot of the Blender interface after applying the rig.

Source: Authors

Figure 13. Blender interface for facial rig demo.

Source: Authors
3.6 ANIMATION

Initially, the use of motion capture animation through the Motion Builder software was considered. However, due to time constraints, character animation was exclusively carried out within the Blender software. Animation was achieved through the most common method in 3D production, employing keyframes (the manipulation of points to create a pose that the artist uses to represent a specific frame) and frame interpolation using the graph editor, which utilizes curves to represent the generated motion[8].

Furthermore, with the aim of expediting production, the Mixamo platform was once again employed. In addition to its rigging capabilities, it also allows for the free importation of motion capture animations into your project [9. From there, adjustments were made to harmonize the visual style with the rest of the piece.

4 RENDERING

According to [8], "rendering, the final stage of the 3D production pipeline, takes 3D models, rigs, animation, shaders, textures, 3D visual effects, and lighting and compresses them into a 2D video or static images".

For rendering, the authors used their personal computers, equipped with a Ryzen 5 5600h processor and a Geforce RTX 3050 Laptop. One of the main challenges encountered during rendering was the limited amount of VRAM or video virtual memory on the graphics card, which was only 4GB. This limitation affected the size of textures and the number of objects in the scene. Therefore, each scene was adjusted so that only essential elements were present, unused textures were removed, lighting was optimized, and polygons of distant props from the camera were reduced.

4.1 EXPORT SETTINGS

The Blender software operates with three different rendering engines: Workbench, similar to the one shown in the program’s interface, designed for quick processing and used for keyframe testing and pacing; Eevee, which employs rasterization-based materials and lighting, offering a suggested option for rapid work while still achieving high-resolution results; and Cycles, a tool that ensures the most accurate results in terms of lighting and materials but demands
higher processing power [10]. For the work on Icarus, due to limited time and intermediate-performance hardware, both Cycles and Eevee were chosen as rendering engines for the final product. The real-world scenes were rendered in Cycles, while the fantasy world scenes were handled by Eevee.

The export was done in a sequence of PNG images to avoid image compression during the assembly and post-processing stages. The images were rendered at a resolution of 4k (3849x1600 pixels) in a 21:9 aspect ratio, also known as ultrawide, commonly used in cinema for its cinematic visual aesthetic resulting from the distortion caused by anamorphic lenses [11].

4.2 RENDER OPTIMIZATION

Within the ray tracing-based rendering defined, as in the case of the Cycles tool, support was provided for emerging technologies found in NVIDIA's RTX graphics cards, which are equipped with RT cores designed to handle ray tracing calculations swiftly through the use of APIs. RT cores are a specialized component in certain steps of the ray tracing processing pipeline, aiming to significantly reduce the time required to perform all procedures for calculating the rays of light in the scene [12].

Regarding the sample count, due to the 4K resolution, a higher number than 800 samples would be required to avoid noise. However, the use of denoising technology was employed. A “sample” refers to the pixel sampling for light, similar to the ISO of a physical camera. For instance, a sample of 200 will calculate how light is reflected and absorbed in that pixel 200 times in comparison to other ambient lights. More samples result in less noise in the final image [13]. Denoising is an artificial intelligence process that seeks to reduce image noise through calculations of adjacent pixels. Thus, with 200 samples per frame combined with denoising, satisfactory results were achieved.

For comparison, a frame rendered using the CUDA API took 9 minutes and 54 seconds to complete with 200 samples, while the same frame rendered using the OptiX API only took 1 minute and 32 seconds to finish. This represents approximately an 86% reduction in rendering time when using the OptiX API within Blender. Therefore, the CUDA API is a general-purpose tool for all types
of graphics cards, while OptiX enabled accelerated ray tracing specifically for NVIDIA's RTX graphics cards.

**Figure 14.** Render time comparison between CPU (Blue), CUDA (Grey) and OptiX (Green) in different scenes.

For the final assembly of the project, it was necessary to merge all the scenes created by the authors. Each scene was exported from Blender as sequences of PNG images and imported into video editing software. Adjustments and cuts were made during the animation assembly to achieve greater synchronization accuracy with the soundtrack.

The last stage of the development of the animated music video "Icarus" is its publication and distribution on the digital video platform YouTube. After ensuring the necessary formatting for video submission on the website, the file was uploaded in MP4 format with a 4K resolution. The music video can be accessed via the following link: https://www.youtube.com/watch?v=KWExzK6dvos.
Figure 15. Final render for the “Real-world” environment.

Source: Authors

Figure 16. Final render for the “Fantasy” environment.

Source: Authors

5 CONCLUSIONS

One of the major constraints that hindered a portion of the production was the available hardware, as the challenge was to rely solely on the authors’ home computers for rendering the project. While rendering with the Eevee engine in Blender yielded satisfactory results, they were not ideal for achieving the initial proposal without relying purely on ray tracing rendering, as in the Cycles tool.

In the event that rendering on home hardware is not feasible, there are alternatives such as cloud or remote rendering available through subscriptions or project-based packages. Another option would be to halve the rendering time by exporting the project in Full HD (1080p) resolution. However, with the current trend of 4K Smart TVs and the rise in resolution over the last decade, choosing 4K was considered a future-proofing measure.
The use of emerging technologies such as the RT cores in RTX graphics cards was crucial for optimizing ray tracing rendering, enabling extensive rendering production with a significant reduction in time.

With the completion of the description of the process of the audiovisual work "Icarus" and the demonstration of the tools used to optimize the modeling and rendering processes, it is hoped that there is clarification on how the development of music videos can be managed to ensure that 3D becomes an assisting tool for artists, quickly and without the need for a high budget for independent productions.
REFERENCES


