The Icarus project: pipeline for low-cost computer graphics animation

O projeto Icarus: pipeline para animação de gráficos de computador de baixo custo

DOI: 10.55905/oelv21n10-209

Recebimento dos originais: 22/09/2023
Aceitação para publicação: 23/10/2023

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ABSTRACT
This article addresses the process of creating a music video called Icarus using low-cost 3D animation, to be carried out efficiently within a short timeframe, under a student production. Throughout the text, various stages of development are explored, spanning from the initial planning and pipeline setup to the modeling, animation, and rendering phases. Guidance will be provided on suitable techniques and relevant software that can support amateur artists in achieving the desired final outcome.

Keywords: computer graphics, pipeline, cost-efficient, animation.

RESUMO
Este artigo aborda o processo de criação de um videoclipe chamado Icarus usando animação 3D de baixo custo, a ser realizado eficientemente em um curto período de tempo, sob uma produção estudantil. Ao longo do texto, vários estágios de
desenvolvimento são explorados, desde o planejamento inicial e a configuração de pipeline até as fases de modelagem, animação e renderização. Serão fornecidas orientações sobre técnicas adequadas e software relevante que possam apoiar os artistas amadores na obtenção do resultado final desejado.

**Palavras-chave:** computação gráfica, pipeline, custo-eficiente, animação.

1 INTRODUCTION

Since its emergence in the 1960s, computer graphics animation has undergone a series of transformative changes, and it is now preeminent across a multitude of media domains. Its influence extends from film and television to advertising and education. Despite its widespread popularity, the challenges of cost and the limited accessibility of sophisticated equipment persist as significant issues to this day (BEANE, 2012).

The growing demand for enhanced productivity is evident, particularly in a job market where contractors are continually securing services at increasingly lower costs (GELISEN, G.; GRIFFIS, F. H., 2014). As a result, individual artists must find tools to enter this field, enabling them to compete with more intricate production pipelines.

“The Icarus Project” revolves around a 3D animation designed for a musical videoclip, tailored for a local student group. In tackling this effort, it was crucial to devise a swift and efficient approach to cost-effectively produce the animation. With a team of just two members and supervised by a professor advisor, a one-minute animation was crafted, leveraging limited resources and minimizing expenses wherever feasible.

The scope of the project centers on a character named Icarus, set within two distinct scenarios: a concert stage and an enchanting forest. These divergent landscapes serve as integral settings that Icarus traverses over the course of the narrative progression, but also imposes an extra challenge for the production by building two completely different scenarios, from objects and props to lightning and mood.

The majority of the work on the project was carried out using the free and open-source program, Blender. The program is capable of providing all pivotal steps in 3D animation: modeling, rigging, animation, simulation, rendering and even motion tracking,
all without the need to rely on multiple separate software tools which would consequently increase the project’s costs.

To meet the artistic stylization expectations set for the project, the Adobe Substance Painter program was employed as a tool to supplement the resources already harnessed within Blender. Within it, texture mappings were executed, subsequently painted to replicate handcrafted brushstrokes. In alignment with the project’s intent, Substance Painter is available for student use at no cost.

While the project’s objective aimed to minimize expenses, it proved unfeasible to avoid the investment in the computer infrastructure deployed for its development due to the time available for production. In the execution of the Icarus project, a laptop endowed with 24GB DDR4 3200MHz RAM, a Ryzen 5600H processor, and an Nvidia RTX 3050 graphics card were employed, enabling the team to meet the deadline imposed by the university schedule. While these specifications surpass the minimal requisites, it is advisable to opt for components of comparable potency to those utilized.

2 PIPELINE

The development of the animation is divided into three stages: pre-production, production, and post-production. However, this article will focus on the production phase, where most of the cost-cutting measures can be implemented. The production methodologies discussed by the author are primarily based on those suggested in the book “Producing Animation” (2019), by Catherine Winder and Zahra Dowlatabadi, along with the more simplified perspective for the 3D animation process in (BEANE, 2012).

The pre-production phase resembles the approach outlined by Winder and Dowlatabadi for developing a 2D project, wherein the entirety of animation conception was executed using this method. This alignment persists until the "animatic" stage, a video made by rough drawings that syncs the main actions with audio. Moreover, the model was synthesized to cater to the requisites of a non-commercial, low-budget production, as illustrated in Figure 1.
During the production phase, the focus shifted towards the execution of a 3D project. Beane simplifies the process into 9 general linear steps. Conversely, the approach presented in “Producing Animation” breaks down the work's development to accommodate a larger team working concurrently. Just as in the pre-production stage, the author adapted this phase to comprehensively address the two-person team, as depicted in the diagram in Figure 2. Simultaneous production during the modeling and texturing phase proved essential in optimizing time throughout the project.
3 PRODUCTION

With the aim of testing various methods and approaches to animation development, two environments were created: the stage and the enchanted forest. Within these environments, different forms of modeling, texturing, and lighting were explored. Additionally, a character was designed to interact seamlessly with both environments.

3.1 CHARACTER

“Icarus” was the first character to be modeled, as it is also the most intricate model in the project. The approach chosen by the creators is commonly referred to as "poly by poly," involving the three-dimensional construction of the object face by face, based on references from a "model sheet." For finer character details, especially to enhance facial animation, particle system resources were employed for the hair, and sculpting techniques were utilized to define the eyelids.
Subsequently, the character’s rigging test was conducted. Rigging is the phase that involves creating motion controllers for a geometric object to facilitate the character or object animation process (BEANE, 2012). At this stage, the free digital platform Mixamo was introduced. In addition to offering editable animations created through motion capture, the website also allows importing custom models to automatically generate their skeleton, or rig (ADOBE). Furthermore, other resources were necessary to enhance interaction between Blender and Mixamo. Plugins, software components used to add functions or features to larger programs, were integrated into Blender to introduce facial controls (the "Rigify" plugin) and optimize the Mixamo-generated skeleton more effectively (the "Mixamo add-on" plugin).
3.2 PROPS AND ENVIRONMENT

Simultaneously with the character production, the modeling and texturing of props and elements of the scenes were implemented, where the modeling technique used for the

Figure 4. Blender interface screenshot

Source: (project’s author)

The texturing of “Icarus” was carried out using two different software programs, Blender and Adobe Substance Painter. The incorporation of both software programs allows for a greater variety of materials and textures, ranging from the most realistic to the most stylized, as shown in Figure 5.

Figure 5

Source: Authors
objects differed from that of the character. Known as "box modeling," this method involves using geometric shapes as a base to sculpt the final object (JONAITIS, 2014). However, during the process, it was observed that various elements in the scene that didn't contribute to the narrative of the work were taking too much time to be modeled. Therefore, the authors utilized freely available 3D models from the internet to optimize the production pipeline and progress to future stages. To achieve this, after the inclusion of imported elements, the textures were remade to align with the art direction.

Figure 6. Blender interface screenshot

Source: (project’s author)

In the second environment, the enchanted forest was characterized by more stylized textures, and new methods of composing the scene were introduced. Among them, the particle system stands out, which was used to create the illusion of grass by simulating hair (figure 7), and the "geometry nodes," a function capable of modifying the geometry of an object through various calculations (BLENDER), as shown in figure 8. This system was crucial for creating the trees, as they were replicated multiple times, thus reducing the file's volume.
3.3 ANIMATION

The character animation was done entirely within the Blender software, using the most common method in 3D production, which involves applying keyframes (poses created by the animator to represent a specific frame) and interpolating frames using the graph editor, which uses mathematical curves to represent generated movement (BEANE, 2012).

Additionally, the Mixamo platform (Figure 9) was once more utilized for the integration of pre-made animations. On the website, it is possible to apply motion-captured files to the desired character's structure. From there, the animation is
implemented into the model and refined to better fit the scene. This iterative approach not only accelerated the project, but also ensured its timely completion.

Figure 9

Source: https://www.mixamo.com/#/

Building upon this foundation, our character's skeleton operates in two different modes: FK (forward kinematics) and IK (inverse kinematics). The first allows you to pose your character like an articulated doll, where the hierarchy works, for example, from the shoulder to the character's hand. Conversely, IK works the other way around, allowing you to position the character's hand to a specific location where the shoulder and elbow adapt to the movement (BEANE, 2012). The ability to switch between the two systems provides greater flexibility for the desired animation.

The facial rig of “Icarus” was customized based on the groundwork provided by the "Rigify" plugin, shown in Figure 10, which enables the movement of the eyes, mouth, eyebrows, and facial muscles, allowing for character expressions.
3.4 LIGHTING AND RENDERING

Following the animation refinement, the next steps involved setting up lighting and final camera positioning. In Blender, the environment, often referred to as the "world environment," is responsible for defining the background and general lighting of the scene. This includes solid colors, textures, sky simulations, or HDRI images, a set of techniques that allow a far greater dynamic range of exposures than normal digital imaging techniques (BLENDER). In The Icarus Project, since the two existing backgrounds have varying levels of realism in their textures, the ambient lighting must follow the same principle. For the first, called the stage, a free HDRI image was assigned to simulate the local lighting. This approach works well in an enclosed environment where the realistic image background can be hidden.

On the other hand, the open space of the enchanted forest required aligning the "world environment" with the designated artistic direction. To achieve this, a procedural texture was developed. Procedural textures are mathematically defined textures that can be edited at any time (BLENDER). Once the environment presets were established, a dome enveloping the entire scene was introduced to replicate the presence of clouds in the sky. In this context, procedural textures were once again employed, as exemplified in Figure 11.
Ultimately, following the completion of the final composition for all scenes, the last phase of the author's structured timeline was executed: the rendering. At this juncture, all previously produced components, including models, rigs, animations, shaders, textures, and lighting, are converted into a 2D video or static images (BEANE, 2012).

Among the various rendering engines accessible within the Blender software, the most fitting one for the project was selected, known as "Eevee." Eevee operates in real-time, enabling interactive usage during scene development. Divergent from the individual ray computation approach of the Cycles engine, Eevee employs rasterization to process the scene. This entails approximating light-object interactions via algorithms, as opposed to tracing each individual light ray (BLENDER).

The final stage in the development of the animated music video, Icarus, involves its upload to the video platform YouTube. Following the adherence to the required formatting guidelines for video submission on the website, the file was uploaded in MP4 format. The full animation can be accessed via the link https://youtu.be/KWExzK6dvos?si=_DaYR5YWtb9ENbUP.
4 CONCLUSIONS

For the computer graphics animation, Icarus, in order to establish an organized schedule and showcase the process of 3D animation for music videos, the author developed production diagrams, clarifying the necessary steps during the construction of the work. All stages were executed as planned, as the entire animation creation, from the initial stages of pre-production to its final rendering, was completed within 7 months, fitting within the timeframe demanded by the university schedule.

The pre-production of the work was kept simple to meet the deadline, as the entire 3D production process would follow later. With material studies being conducted only during the modeling stage, the art direction pre-established by the authors deviated from
what was achieved. Nevertheless, various new elements were introduced to resemble the desired outcome, such as the use of procedural materials that mimic traditional art, instead of being manually painted through the Adobe Substance Painter program.

The production phase of Icarus proved to be more complicated than anticipated by the authors. Due to the inexperience in producing a more complex project, misguided decisions were made at the beginning of modeling. After realizing that modeling all secondary props in the scene would not be efficient, the authors looked for freely available models, with materials adjusted to fit coherently with the art direction of each environment. This allowed them to proceed to other complex production stages, such as rigging.

Once again, production speed proved to be essential in delivering the work on the desired schedule. To achieve this, the use of the Mixamo platform for rigging the character of “Icarus” was considered from the beginning of animation creation. Moreover, due to the familiarity developed during this stage, animations available through motion capture on the same website were also utilized. The compatibility between Blender and the files generated by the platform was efficient, but complex. Blender is a platform that is in constant evolution, and during the course of the project, it did not yet have proper support for motion capture editing. Thus, it is recommended to explore programs focused on this type of animation, such as Autodesk’s MotionBuilder, which is also freely available for students.

The rendering generated by the Eevee engine in Blender provided satisfactory - but not ideal - results. Constrained by the tight time frame, the authors’ intention was to use the Cycles tool, as it provides higher quality in the final product. Therefore, the production of a new rendering is already being considered to refine the delivery without time limitations.

In conclusion, although it may not yet reach the scale of major studio productions, the methods and tools presented have the potential to offer distinct advantages to amateur artists within the job market, making it feasible to create animations of a certain level of complexity even with a limited budget.
REFERENCES


