Rendering process and methods for creating stylized and photorealistic computer-generated 3D characters for video games development with their comparison

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Abstract

Computer Graphics combined with modern technology and complex rendering solutions with 3D visualisation enabled digital art could become the most widespread form of visual art in the world. The video games industry and movie production with computer-generated imagery opened a new field for graphic technology using strong rendering infrastructure. Man has been the main point of interest of art for millennia until today. There are two basic ways of depicting characters: stylized and photorealistic.

Over the years the process of creating digital signs is not linear, which means that in most cases it is necessary to jump between steps. The workflow will depend on two key factors, which are the style and the use of 3D characters. More complex designs require more attention to detail, which affects the process and length of the workflow. Digital 3D characters can be used in video games, movies, visual graphics, 3D printing. Characters used in games will have significantly fewer polygons than movie-ready characters, while 3D-printable characters will have their own set of rules that make them printable.

Complex graphics combined with strong computer power and high-end performances offer huge progress in digital art. Regardless of the different styles and use cases, there are certain workflow steps that stylized and photorealistic characters share, namely: design and references, retopology, UV unwrapping, texturing and materials, scene setup, lighting, rendering, and post-production processes. This paper compares the workflows between stylized and photorealistic characters and their advantages and disadvantages.

Key words: CGI, workflow, 3D modelling, rendering, UV mapping

1. INTRODUCTION

From the very beginnings of the existence of art, the main interest of creativity has been man and the animals that surround him. As culture and art developed, creativity got the opportunity to interpret man in unique ways. The artistic representation of people can be presented in a minimalist way, like the drawings on the famous walls of the French Lascaux cave, but also in a realistic representation, like David sculpted by Michelangelo. Today's time and technology open the door to non-destructive processes of painting, sculpting and illustration, which offers great opportunities to develop new styles, but at the same time to push the boundaries of creating characters to a level of realism never seen before. Today, human characters are especially popular in the video game and movie industries.

This paper describes the rendering process and compares the methods of creating standard stylized and photorealistic 3D models used in movies or video games. Their advantages and disadvantages are compared and the usability of the 3D models themselves affects the workflow.

2. REFERENCES

In the context of creating 3D characters, references represent a collection of photos, renderings and illustrations that can serve as inspiration, a guide, and a mental map. It is used to present various ideas in the form of a collage.

When talking about references intended for the creation of realistic 3D characters, it is understood that the focus will be on a collection of illustrations, photographs and 3D models of the anatomy of the human body. The goal for modellers is to find as many references as possible that show the same motif from as many different angles as possible in order to get the best possible sense of form.

References that will be used to create stylized 3D models will focus much more on a set of illustrations, drawings and previously made 3D characters. In this workflow, the modeller emphasizes developing a quality and convincing style as opposed to photorealistic characters that imitate reality.

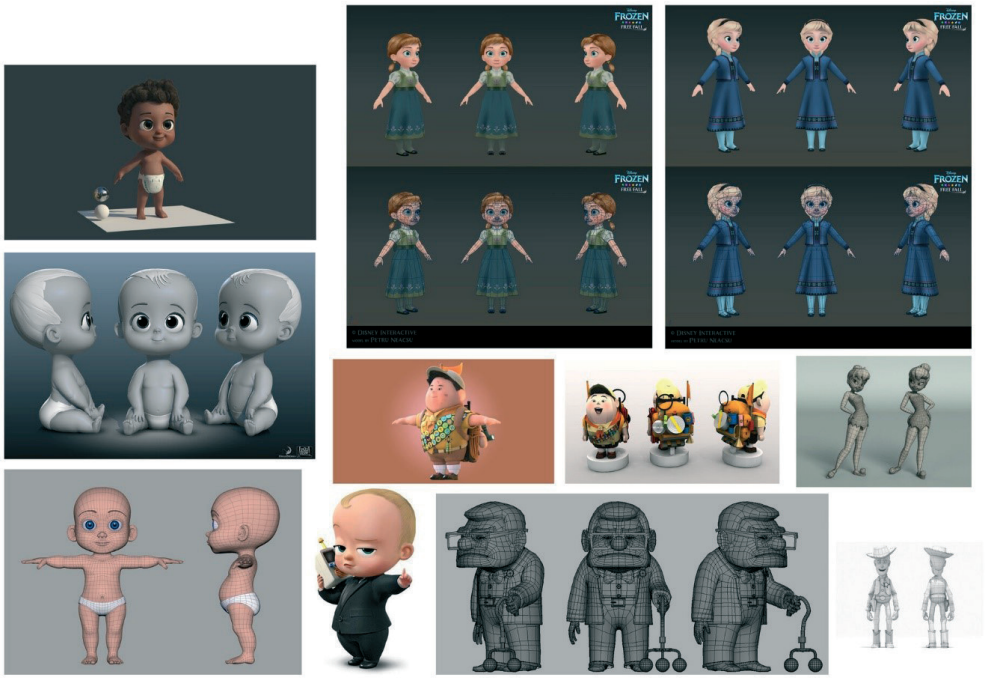

Figure 1: An example of a collection of references intended to create a stylized character [1]

3. SCULPTURES

Sculptures are all three-dimensional forms whose purpose is artistic expression. In addition to art, sculptures can also have functional roles, which can often be found in architecture. Sculptures can be described with several elements, namely: surface, mass, line, surface, colour and light and shadow. [2]

Today, the easiest way to make sculptures is in digital form. Digital sculpting is a type of 3D modelling based on the use of 3D software to manipulate polygons in a way that simulates the shaping of real matter such as clay. Programs intended for digital sculpting allow artists to quickly and intuitively shape a three-dimensional form. The greater the number of polygons used, the greater the freedom of the 3D model.

Digital sculpting best finds its purpose in modelling irregular, organic shapes that are very time-consuming and demanding to model with traditional modelling methods, which is why digital sculpting is the perfect choice of method for creating human and animal figures. This type of modelling is also very often used to precisely add textures, details and irregularities to surfaces.

As digital sculpting is a form of 3D modelling, it is the first and basic step in creating 3D characters. This modelling method allows artists to quickly and easily make major changes to their 3D models and thus make the right design decisions in the early stages of production.

The creation of digital sculptures of characters begins with the shaping of primary forms where the artist manipulates the polygons through various options of pulling, squeezing and smoothing until the targeted results are achieved. [3] The resolution of the model, the number of polygons, increases gradually during creation, and by increasing the resolution, secondary and ultimately tertiary forms are modelled, which represent fine details on the surfaces.

When creating photorealistic 3D characters, and especially human portraits, it is necessary to pay special attention to details. During this process, the use of references is crucial and can ultimately determine the quality of the model. Realism sets a high standard that needs to be achieved and it is necessary to achieve good forms from all possible angles, everything from the primary and secondary forms of muscles, fat deposits and bones to the tertiary forms of pores and folds on the skin.

A key factor in creating stylized 3D models is the fact that they do not imitate reality but caricature it. Stylized sculptures of characters are most often simplified down to their basic forms, and special emphasis is placed on the simplification of primary forms. Like photorealistic models, stylized models can also be enriched with tertiary details, although this step is not necessarily necessary to achieve convincing results.

Figure 2: Comparison of two sculptures: photorealistic and stylized figure [4]

4. RETOPOLOGY

Retopology is the process of optimizing an already existing topology in order to ultimately make working with models easier. It is a process that is carried out with objects that are modelled by the process of digital sculpting and consist of a large number of polygons or with models whose topology is generated such as 3D scanning. [5] The goal of retopology is to keep the same shape of the existing model but to use as few polygons as possible.

The retopology process is inevitable with all models intended for video games and movies. Whenever it is necessary to deform the topology of the model, regardless of whether it is animations or simulations, the process of retopology will be necessary in order to achieve the most credible and computationally optimal results. Retopology is also a key process in situations where you need to texture models and view them in real-time. The clean topology of the model enables fast computing performance. That being said, models that are not intended for animations, simulations and texturing processes will not require retopology. The best examples of such models are those intended for 3D printing.

The retopology process is a relatively complex process that has not yet been automated, which is why the best results are achieved by manual modelling. Automatic retopology methods are slowly being developed, while manual retopology remains the only option for achieving optimal results.

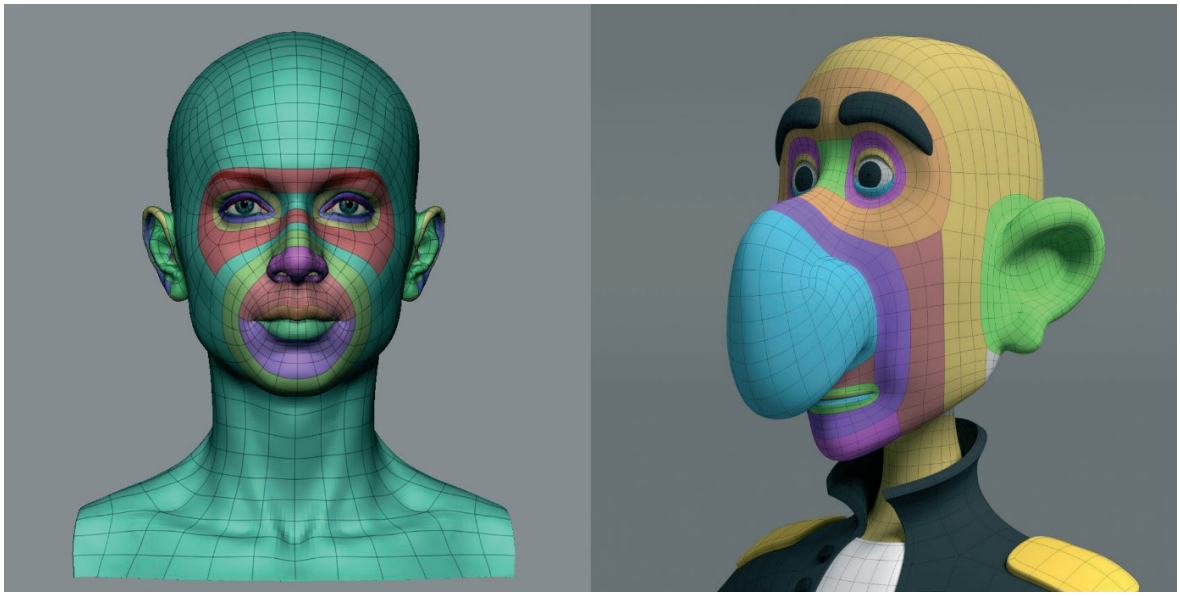

Figure 3: Application of pure topology on a photorealistic and stylized character [6]

5. UV MAPPING

UV mapping or UV projection is the process of projecting a 3D surface onto a two-dimensional space or texture. The labels U and V replace the X and Y axis because those along the Z axis are already used to define 3D space. This process represents the unpacking of the 3D surface of the model so that the surfaces are laid as flat as possible on the two-dimensional surface and the desired textures are projected onto that laid surface.

In the case of irregular organic shapes, the unpacking of the 3D surface will never be completely flat and a certain part of surface deformation will always be present. The most important factor in UV designing is the use of seams. All edges that will separate the surfaces from each other during unpacking are called seams. Seams enable greater control over the unpacking of the model's surface and are a key factor in achieving optimal results, because with their tactical positioning, the number of deformations can be reduced to a minimum.

UV mapping is a process performed as part of texturing. The better the retopology and UV design methods are, the better the basis for the texturing process will be.

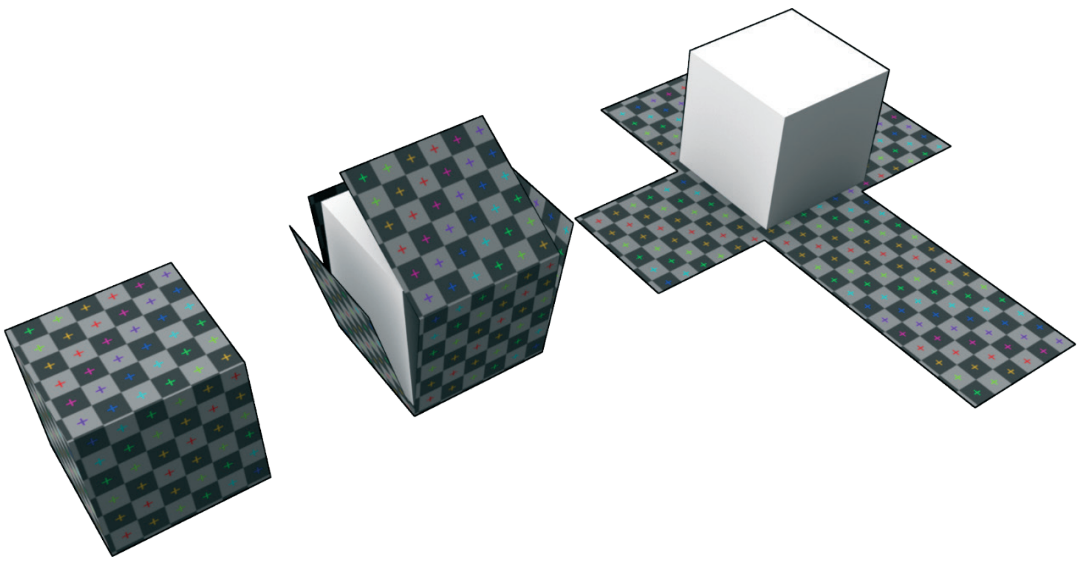

Figure 4: Basic UV surface unpacking shown on the example of a cube [7]

6. TEXTURING

Texturing is the process of applying colours and materials to 3D models. In addition to providing colour to 3D models, textures are often used as carriers of information about the reflectivity and transparency of the model's surface. [8] These are black and white textures where black represents the lowest value or zero, and white represents the highest value or one. Textures are also very often used as masks for precise control of different layers and as so-called normal maps. This type of texture "fakes" the geometry by giving information to the light on how to react with the surface it hits. This method adds small details such as scratches and pores on the skin while maintaining optimal computer performance. These textures are almost always used in the creation of video games and movies.

There are two basic methods of applying textures to models. One method involves the manual application of textures to surfaces, i.e. painting. This method allows greater control and better-quality results. Another method is the method of procedural texturing, where already existing textures are projected onto the surface of the 3D model in the form of a repeating pattern. The advantage of this method of texturing is that quality results can be achieved relatively quickly.

The textures used for photorealistic 3D models of human characters are very complex due to the large number of variations not only in colour but also in skin properties. A thorough knowledge of anatomy and an understanding of the relationship between the venous system, fat deposits and muscles is necessary to achieve convincing results. The more variations and details such as pores and folds on the skin, the better the results. In addition to the colour itself, a strong knowledge of the characteristics of the skin is required. Certain parts of the body, especially the face, reflect light in specific ways. Black and white textures control the reflection of the face. Another factor that makes human skin specific is the fact that it lets a good amount of light through. This effect is called subsurface scattering. A good understanding of the skin, its properties and texturing methods are a prerequisite for achieving realistic and convincing results.

Textures to be used for stylized characters vary a lot more in terms of acceptability. Since such models are highly dependent on the predetermined style, textures with a large number of variations as well as simple textures can give excellent results. The most common form of textures used for stylized models are simplified realistic textures. Variations are usually added around key body parts such as eyes, nose and lips without having to apply all skin irregularities.

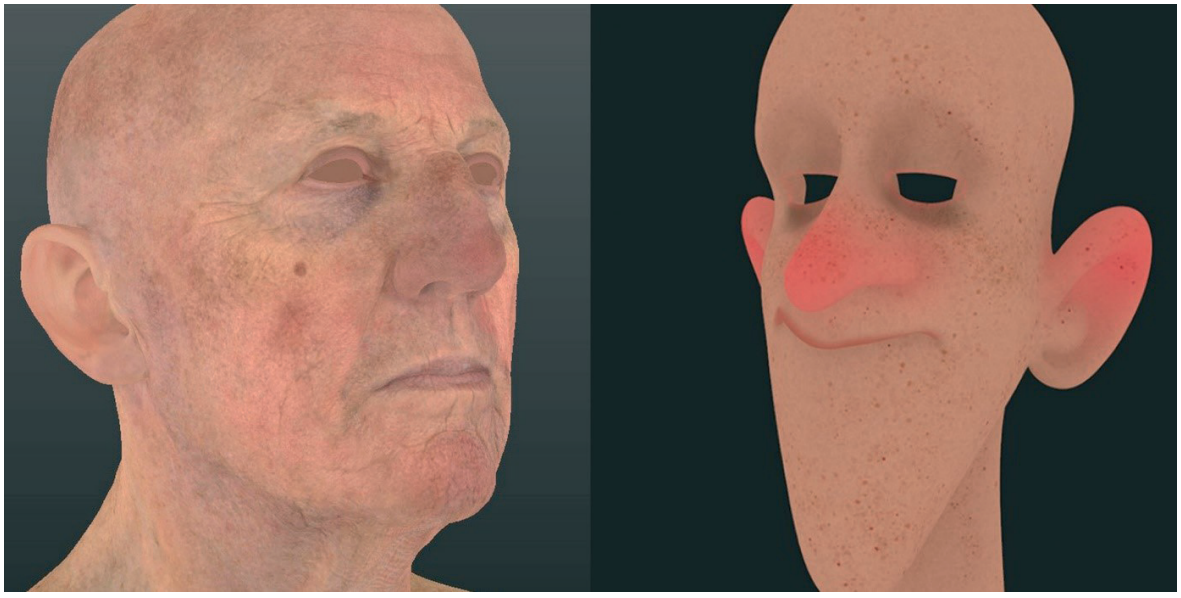

Figure 5: An example of the texture of a photorealistic and stylized human figure [9]

7. SCENE SETTING AND LIGHTING

The final setting of the scene involves posing the character and bringing it into the appropriate environment. Characters are rarely rendered without a background, and their complexity can vary from detailed modelled environments to simple two-dimensional backgrounds that create a parallax effect. The parallax effect is a phenomenon when elements in the foreground move faster than elements in the background of the scene. [10] In this way, the illusion of 3D space is created using only two-dimensional images.

Placing the characters in the desired poses is done with the help of a digital skeleton that serves as a controller for deforming the geometry of the model. This method of character posing is used for all character animation needs, whether in video games or movies. [11] Another option for posing is to use the blend shape or shape key tool. This is an option that allows you to determine the initial shape of the geometry and the final one, and the computer will automatically create a linear transition from one shape to another. This method is not particularly flexible from the perspective of the animator, but it gives extremely precise results, which can be very useful when working with the generation of facial expressions of characters.

Setting up the scene also means setting up the camera and its properties. Since the camera plays an important role in the composition, it is necessary to define its properties such as resolution, focus and focal distance. Another important element of composition is lighting. In addition to being used for elemental lighting of the scene and characters, light is used so that the artist directs the viewer's gaze to a specific part of the frame and through the elements of light and shadow, emphasizes important and hides less important motifs of the scene and thus achieves solid visual communication.

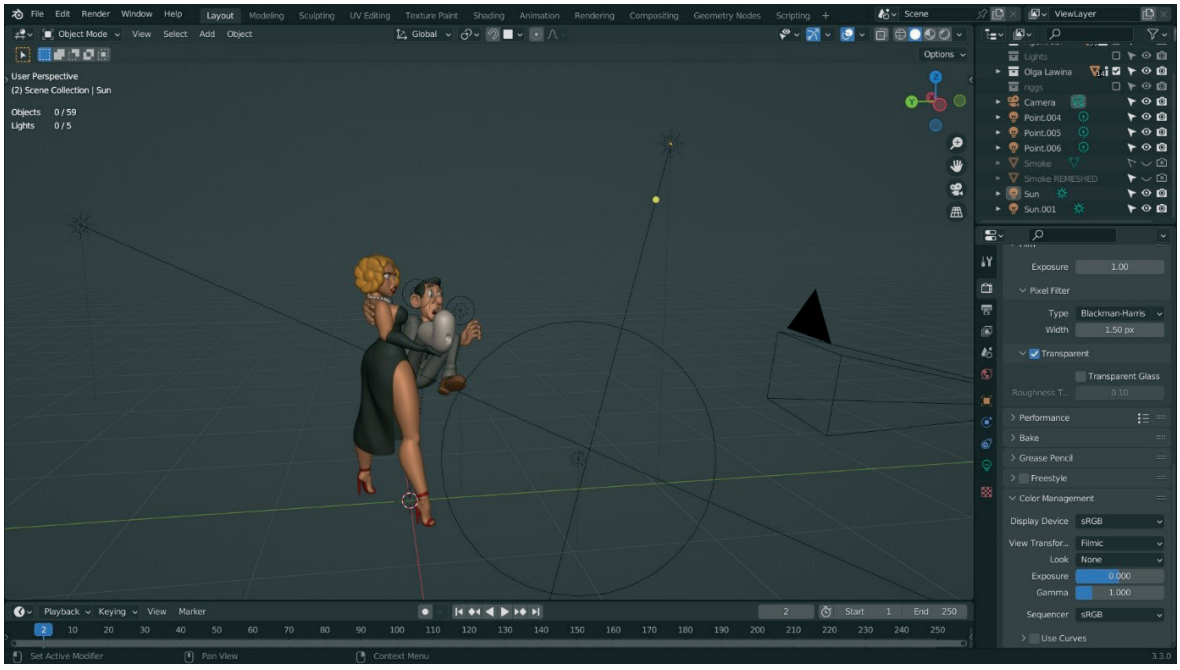

Figure 6: Set scene with posed characters, added camera and lighting [12]

8. RENDERING AND POST-PRODUCTION PROCESSES

Rendering is the final process in creating CGI for any kind of multimedia purpose. In the context of 3D modelling, it is the process of converting a 3D model into a two-dimensional image or render. The best algorithm for rendering 3D space uses a technology called ray tracing. This method simulates real light and its rays that are reflected from all the objects they hit. Computer programs use a wide range of advanced algorithms to calculate the path of light rays as precisely as possible. The better and more precise the calculation, the more realistic the renderings.

After the so-called raw render, i.e. the render that was generated directly from the 3D software, the stage of final rendering in post-production software follows. Post-production processes are

the fine and final editing of the image, which includes adding special effects, filters, colour ratios, and adjusting lighting and exposure. Post-production is followed by final rendering.

9. PRACTICAL PART

For the purposes of the practical part, two models completely made in Blender will be compared. It is a photorealistic portrait and a stylized character. On the basis of the theoretical part, the approach to creating these two characters will be compared, as well as the possibilities of tools in Blender. Blender is one of the few 3D software that has a wide range of tools that vary from digital sculpting all the way to final rendering and post-production.

9.1 SCULPTURES

Digital sculpting usually starts with a low-resolution sphere model. In these early stages, the goal is to define the basic outline of the character. Blender has great tools for dragging, adding and deleting polygons that are quick and easy to work with. For the needs of a photorealistic character, photographs are used as references. The more different angles, the better, because in that case, it is easier to realize all the necessary forms. In addition to photos of the subject, it is a good idea to use general references to the anatomy of the human face.

The gradual addition of resolution defines the primary and secondary forms of the portrait, that is, all the forms formed by bones, muscles and fatty tissues. Only at that moment is the model ready to add a high resolution that allows fine details of pores and folds to be applied to the skin. Also, when defining the skin, a good analysis of the references is recommended, because the skin is not a simple collection of pores and moles. It reveals a lot of information about the age of the person being modelled, which is why inconclusive results are immediately noticed.

During the sculpting of the stylized figure, references to previously modelled figures were used to roughly define the direction in which the model would develop. The character is made in the general style used for feature-length 3D films and some characteristics of these characters are big eyes and nose, round and rounded shapes, big lips, etc. The reason for emphasizing facial elements is to achieve more legible expressions of emotions. This stylized character was created using the same tools as the realistic character, with no tertiary forms added.

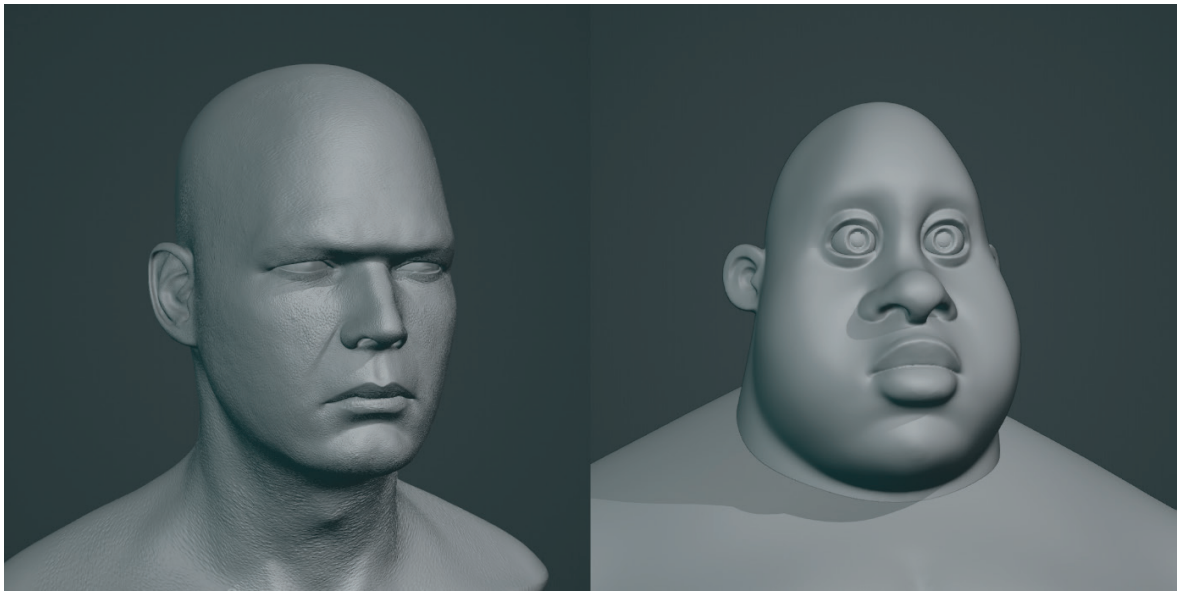

Figure 7: Comparison of photorealistic and stylized character sculptures

9.2 RETOPOLOGY AND MODELING

Blender is one of the best retopology and modelling software on the market today. Although the software itself is very versatile, modelling is its strongest point. Blender offers a wide range of modelling tools as well as quality extensions that significantly facilitate certain modelling processes. The only difference between the retopology of the photorealistic and stylized model is that the photorealistic model has a much larger number of

polygons. Since a photorealistic portrait is much more detailed than a stylized one, the goal is to add enough polygons to retain all the necessary detail while using the least number of polygons possible. During this step, all necessary accessories that do not belong to the retopology, such as clothes, eyeballs, oral cavity, teeth, tongue, etc., are modelled.

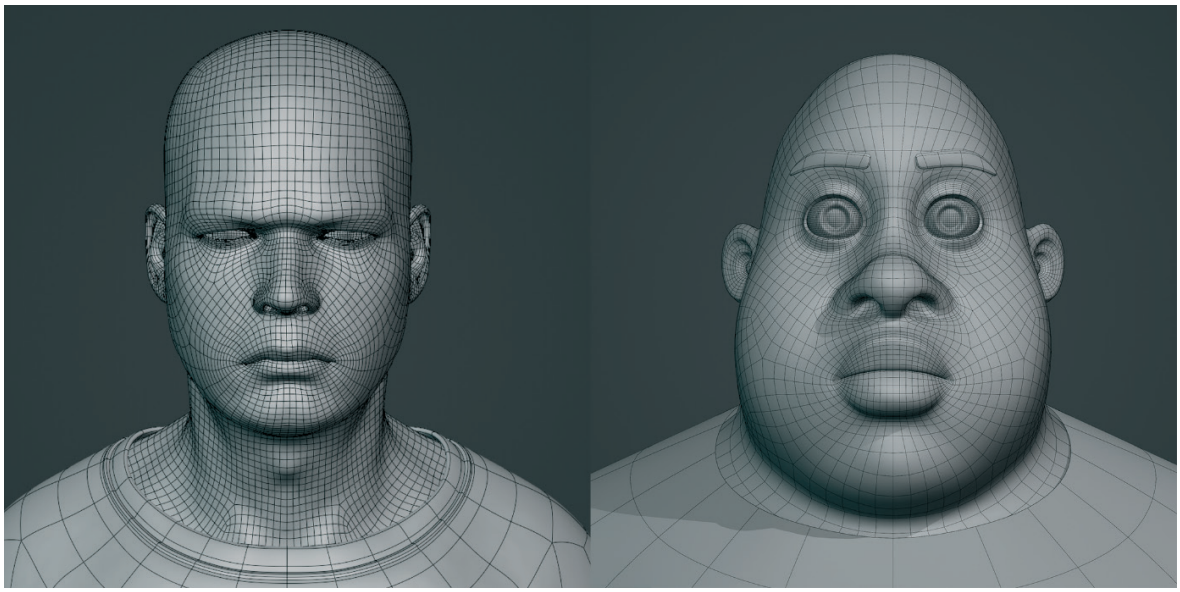

Figure 8: Comparison of the topology of a photorealistic and stylized character

9.3 TEXTURING

Blender is a powerful program that offers the possibility of directly applying colours to models, as well as the procedural generation of textures and materials. A combination of these two texturing methods was used to create a photorealistic model. In this way, a large number of variations in skin colour are realized, which ultimately gives convincing results. After texturing, eyelashes, eyebrows, hair and beard hair are added to the photorealistic model. Hair in Blender works based on a particle system. The particle system in Blender is objects, usually thousands of them, that are emitted from some other object. [13]

In this case, the stylized character is textured in a much simpler way, and this simplicity of the colour palette suits the minimalist style of the 3D model itself, which is why the character will still look convincing in the final renders.

Figure 9: Comparison of photorealistic and stylized character textures

9.4 SCENE SETTING AND LIGHTING

In addition to modelling, Blender is extremely strong and popular in the field of rendering and lighting. For the purposes of the practical part, both models are illuminated using classic three-point lighting methods. This is the most common portrait lighting technique and as the name suggests, it uses three lighting points. One light source is the key light and it illuminates most of the face and creates the sharpest shadows. Another light source is the light that fills the shadows that are too dark. This gives better control over the shadows and creates a softer gradient or transition between the lightest and darkest points of the model. The third light is a background light that illuminates the model from behind and thus creates an outline. This light emphasizes the silhouette of the model and separates it from its background for easier readability.

Photorealistic portraits can often remain in a neutral pose and still look appealing. Stylized models, however, look awkward if they are in a static pose with no emotion on their faces. Therefore, an expression was added to the stylized figure, which will break the symmetry and make it more attractive.

9.5 RENDERING

Blender uses two basic rendering engines. The first one is called Eevee and works in real-time but does not give physically accurate results. It's great for rendering stylized characters and simple environments. Another rendering engine in Blender is called Cycles. It is far better quality and gives physically accurate and photorealistic results, but it does not work in real-time, which is why this rendering method takes longer. For the purposes of the practical part, both models are rendered in the Cycles rendering engine. After the raw rendering, it is transferred to Adobe Photoshop to add backgrounds and adjust fine details such as noise, contrast and colour.

Figure 10: Comparison of the final renders of a photorealistic and stylized character

10. RESULTS OF THE RESEARCH AND DISCUSSION

The results of the research can be easily presented through the comparison of several parameters, as seen in the table 1. The parameters that most accurately describe 3D models and their workflow are the number of polygons before and after retopology, texture resolution, file sizes and rendering time.

Photorealistic character models support higher parameters compared to stylized models, often seen in high-budget productions. However, stylized characters are also common in such projects. High-polygon and high-resolution models deliver top-notch computer graphics but at the cost of slow performance, requiring high-performance computers. Models with lower demands offer a more economical and faster approach.

In this paper realistic sculpture contains over 12 million polygons, while the stylized one has 'only' half a million. This is because tertiary details like pores and skin folds have been added to the realistic model but not to the stylized one, which, at this stage, consists only of primary and secondary forms. Although tertiary details can be added during texture application, the best method for achieving realistic results is still adding fine details during sculpture creation. The higher the polygon count, the better the resolution for small surface details.

After retopology, polygon counts decrease significantly for both stylized and realistic characters. Retopology aims to maintain shape while reducing polygons for smoother animation and rendering. Acceptable polygon counts depend on usage, from background characters to main characters in film, video games or high-budget computer/console games. Generally, counts range from thousands to hundreds of thousands, with occasional use of millions for extreme close-ups in high-budget productions.

In the paper, both models use 4K textures. Texture resolution for characters varies by platform and audience: video games range from 515x515px to 2048x2048px, high-production games from 2048x2048px to 4096x4096px and film animations from 4096x4096px to 8192x8192px or higher.

Table 1 shows that rendering the photorealistic character takes twice as long as the stylized model, even though the stylized model has more polygons after retopology. This is because the realistic model is rendered with all 12,082,885 polygons to preserve detail and uses more textures and material variations, which increases rendering time.

In the end, there's no fixed polygon count or texture size for character models. It depends on factors like complexity, desired detail, and software/hardware capabilities, balancing visual quality, performance, and artistic goals.

Table1: parameter comparison

	STYLIZED MODEL	REALISTIC MODEL
Number of polygons before retopology	570,277	12,082,885
Number of polygons after retopology	52,435	11,823
Texture resolution	4096x4096px	4096x4096px
File size (MB)	142 MB	257 MB
Rendering time (min)	10:27.48 min	21:14.22 min

11. CONCLUSION

The process of creating 3D characters in theory is quite linear and simple, while practice shows that this is not always the case. Creating characters in 3D software is a time-consuming process that requires jumping between steps and constant repetition of trial-and-error methods. Each character is unique in itself, which means that the creation of each character cannot always be approached in the same way. There are various techniques and tools used to create 3D characters and that work itself will depend on the application of the model (video game development, movie production, 3D printing, animation, simple renders etc.), artistic style and ultimately the author's preferences.

This paper generalizes the build flow to the basic steps required to model, texturize and simply render 3D characters. Both photorealistic and stylized characters are created following the same workflow and each step within the process needs to be approached in a specific way, since they are two completely different artistic styles.

It is believed that the idea of stylized gloating is to emphasize certain features of the human body, i.e. to caricature and simplify reality. These types of characters will usually consist of simple geometric shapes and will be characterized by large eyes, nose, ears or all of them together. These are characters through which the artistic style is emphasized, and when creating them, the author's goal is to create an attractive and aesthetically pleasing design.

On the other hand, models of realistic human characters replicate reality, which is why this is an area that requires much more time, effort and meticulousness. The skill of creating realistic 3D portraits is one of the most enticing areas of art, but also the most demanding to master, which is why this skill is much more valued in the 3D industry. The human face is something that every individual sees all around him every day, and that is precisely why this object is extremely difficult to convincingly transfer to the

canvas. There is no cheating with faces, considering that we humans have become experts in detecting even the smallest anomalies or irregularities that make the face unnatural. This is exactly what makes this skill one of the most interesting but also the most demanding skills in the world of 3D modelling.

In the end, the processes of creating a photorealistic and stylized character are very close, and the final results are completely different, so the final workflow of creating a 3D model will depend on its application, but also on the artistic style that the author has chosen.

The whole message of stylized characters is that they caricature and simplify reality. Such characters will often have large eyes, noses or ears or even all of them together, all with the aim of creating interesting and aesthetically appealing caricatures. Stylized characters emphasize the artistic style. Photorealistic human models require much more time, effort and meticulousness, which is why it is a skill that is much more valued in the 3D industry. We are so used to looking at human faces every day that we have all become experts in recognizing even the smallest anomalies and irregularities in faces that make them unnatural. This makes this skill one of the most interesting and demanding skills in the world of 3D modelling.

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