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Temirlan Shugay[1]*
[1]SDU University, Kaskelen, Kazakhstan
*e-mail: 221107049@stu.sdu.edu.kz

UNRAVELING THE TECHNIQUES AND CHALLENGES OF 3D GAME ASSET DEVELOPMENT

Abstract: The field of 3D modeling is a dynamic landscape closely linked to various industriesand applications, from entertainment to medicine and beyond. This article examines the fundamental aspects of 3D modeling, its applications and provides a detailed description of the process of creating game resources, from conceptualization to implementation, with a description of various modeling methods and tools used in this work. Further, the testing and analysis procedures used to assess the quality and performance of the created resources were carried out. The purpose of this comprehensive study is to give readers a more complete understanding of theintricacies associated with the process of creating models for 3D games.

Keywords: visual effects, 3d modeling, game models, polygonal modeling, topology, texturing, rendering, virtual reality, optimization, visualization

1. Introduction

3D modeling is one of the main areas of graphic design. This is the name of the process of creating a three-dimensional model of a real or intended object. Modeling can be carried out according to drawings, and sketches, or may be accompanied by improvisation. Thanks to this, 3d has firmly entered our lives, partially or completely rebuilding some types of businesses. In each industry in which 3D modeling has brought changes, there are both certain standards and unspoken rules. But even within one industry, the number of software packages can be so numerous that it can be very difficult for a beginner to figure out and navigate where to start.

Several large industries cannot be imagined today without the use of three-dimensional models:

- The entertainment industry: This is one of the most important areas of a person's daily life, which can significantly affect the state of society. These are movies, video games, animation, music videos, advertising and marketing. For example, 3D modeling is widely used in the creation of animated films, both for characters and for the environment. Studios like Pixar and DreamWorks Animation rely heavily on 3D modeling to bring their characters to life and create richly detailed worlds [1].
- Medicine: 3d modeling can be used to create customized implants, prostheses, and other medical devices. For example, based on 3D modeling, you can create an individual prosthesis to replace a part of a bone or joint, taking into

account all the characteristics of a particular patient. Or, during surgery, three-dimensional graphics are increasingly used to visually demonstrate to the patient how the procedure will take place and what the result will be [2].

- Industry: Modern production is impossible to imagine without modeling the company's product. It is easier to assemble every detail or complete object using a ready-made and thoughtful 3D model [3].
- Professional artists use special programs that allow them to create original and unique sketches and in the future often use the development of a three-dimensional model to place their products in electronic catalogs.
- Education: It is used in schools and universities to teach complex concepts such as

anatomy and physics in a more fun and interactive way. 3D models can be used to create interactive learning resources that allow fellow students to visually explore complex concepts [4]. For example, biology students can study 3D models of cells, organs, and organisms to better understand their structure and functions.

In the gaming industry, creating 3D models with a proper pipeline is of paramount importance for efficiency, consistency, quality control, collaboration, and scalability. An optimized pipeline optimizes the entire development process, from concept to implementation, allowing teams to work more efficiently and on a tight schedule. This ensures consistency between assets and projects, maintaining visual consistency and improving the player experience. Quality control measures integrated into the development process make it possible to identify and eliminate problems at an early stage, resulting in a flawless final product that meets high standards. In addition, the pipeline facilitates effective collaboration between different teams by providing clear communication channels and standardized processes. Ultimately, a well-established pipeline not only improves the development workflow but also supports the scalability of projects as they develop.

2. *Literature Review*

The basic type of 3D modeling is polygonal modeling [5]. It occurs by manipulating polygons in space. Stretching, rotating, moving, etc. The point is to build a three-dimensional shape based on a flat surface, which is marked with a grid. The grid consists of lines called edges that intersect at points called vertices. The edges divide the surface into separate polygons. At the software level, actions are performed with edges and vertices until the object takes the desired shape, while the polygons are shifted relative to each other at different angles. The number of polygons can reach huge values. As it increases, the grid increasingly resembles the contours of the object being created, and it becomes more and more as intended. The more polygons per model area, the more accurate and smoother the model is. The collection of vertices and polygons is called a mesh. One solid mesh that is not connected by vertices and polygons to another mesh is called an object.

2.1. **Basics: Building blocks of 3D modeling:**

Vertex is the smallest unit of the 3D model (a point in space).

Edges is a line that is used to connect two vertices. The shape of the object is achieved by manipulating the edges. The face is the part that fills the space between the edges and includes the covered flat surfaces of the model. This is the most basic part of the polygonal grid [6]. A polygon is a shape formed by connected straight lines. The types of polygons are determined by the length of the corners and the number of sides. A grid is a collection of polygons connected by their vertices, edges, and faces. A 3D object can consist of one or more 3D grids [7]. Differences between them you can see in Figure 1.

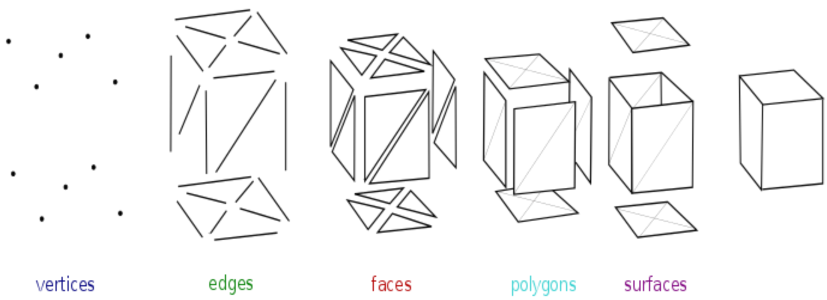

Figure 1. The Visual Representation of 3D Geometric Elements.

2.2 Process of creating game asset

Some points from the process may change places because there are different pipelines, which in the industry is called a sequence of actions or processes, and they may differ depending on the goals and examples of the model.

Stage 1: Concept (creating an idea and implementing it in sketches)

The foundation of any great achievement is an idea. You need to decide what you will create and what your model will look like. Having a drawing will make your task easier. It will also be very important to collect references that already exist in the version. If you have a sketch, drawing and references, it is easier to understand how the model will look and see the chain of actions necessary for their implementation in practice.

Stage 2: Modeling (creating three-dimensional objects)

There are several ways to model:

Drawing polygons. You literally take and draw faces, vertices, and polygons, similar to sketching [8]. In this way, you can get a very accurate result, especially when you need to make a low-poly model exactly according to the concept. In this case, in some programs, you can place an image with an example and “draw” literally on it. However, you cannot make a complete and detailed model in this way.

Primitives. Each program has a set of basic shapes (primitives). A primitive is placed on the work field, and a composition is made of them, deformed, cut and drained. Boolean operations can also be performed here. You may have already heard about this in the framework of mathematics. If not, then it looks like this:

we can add and subtract geometry from one object to another. So, with cylinders, we can make holes in a cube, or make a square window in a sphere.

Sculpturing. Its essence lies in the fact that a new shape is molded from the basic shape (primitive) according to the principle of a piece of clay or plasticine by squeezing and increasing the volume [9]. Large pieces are cut off, fine detail is created with thin tools — just like in real sculpting.

Stage 3: Retopology(optional)

At this stage, we will have to reduce the number of these polygons. Retopology is the rebuilding of a polygonal grid, creating a new geometry on top of the old one for further use. A low-poly grid will be useful primarily for optimization, as well as for creating a clean grid during further animation and creating UV maps [10]. However, retopology is necessary not only to limit the number of polygons. It also allows you to correct defects in geometry, improve the topology of the model and make it more suitable for subsequent processes such as texturing and animation.

Stage 4: UV scan

We need this stage in order for our baking and textures to behave correctly. UV scanning is the projection of an image onto the face of a 3D model [11]. The final appearance of the texture depends on its location, rotation, scaling and shape. To understand the principle of scanning, it is enough to imagine an assembly of models made of paper, but in reverse order — the object is cut and unfolded into flat parts. (example from below in a cube)

Stage 4: Baking

Baking is the stage of transferring the detail from high poly to low poly. Thanks to baking, you can create huge details on lightweight low poly models. The fact is that almost all the highly detailed models that you meet in games are not real. Round smooth shapes on your blade, shell marks on your tank, bolts on your robot, wrinkles on your character — none of this is on the model, it's a visual deception. Therefore, the artist must create two versions of it: the one that will look realistic and contain all the smallest details (High-Poly model) and its simplified version, which the game can pull (Low-Poly model) [12]. The difference in the number of polygons, a measure of model detail, between these two versions can be enormous. A Low-Poly model can consist of a thousand or a hundred thousand polygons and its High-Poly version can number in the millions. Lowpoly has a minimum of polygons and a clean grid. This model will be loaded into the game engine. As a result, all the details from the high-poly model are projected onto the low-poly model.

Step 5. Texturing

A texture is an array of color dots forming an image. It's not just the coloring of the object. In fact, the term texture means the roughness or smoothness of the surface of an object [13]. These are the properties of the surface that can be felt.

It is an important stage in the process of creating and visualizing a 3D product model, which allows you to give the surface of a three-dimensional object certain parameters and properties to make it as realistic as possible and resemble a real object.

Stage 6. Render(optional)

If the goal is to implement a game engine model, then this stage is not important, but submission is mandatory for a portfolio [14]. The portfolio is a modeler's resume, and it is an indicator of his skills and abilities. A bad feed can ruin a good model, and a proper render can save average models. It is important to put a suitable light on the feed, emphasize the volume, add contrast and post-processing. Ideally, add an environment or a beautiful design

3. Implementation:

3.1 Concept of game-ready set:

Since the beginning of anything is an idea, I started thinking about what would be interesting to model, and my choice fell on a weapon. Since I am creating a model for the game,for the sake of the latest trends, I decided that it would be more interesting to create a sci-fi gun.To begin with, I have collected a lot of concepts and pictures that would give me an understanding of how I would like to see my model in the future. I used the Pinterest platform for this purpose.

3.2 Modeling:

For the purpose of modeling, I chose the Blender program(see Figure 2), since it is freeand in its power and capabilities is not inferior to competitors. During the compilation of the
moodboard, I found suitable blueprints for myself, which will greatly facilitate my work. First ofall, I put it on the background and started modeling for it.
I have divided the modeling process into 3 parts:
The draft is a simplified form of the model that we make from simple shapes. Any model startswith a draft.
Blocking is a sketch of a model made of boxes, spheres and cylinders, with which we convey theessence of the object. There are no small details in the blocking, only large and medium shapes. This is how we build the silhouette of the gun to get into its proportions. Detailing - at this stage, we deal with the mechanics of the model so that the viewer believes inits plausibility. It is important to work out the transitions between geometries and think through the key details that provide functionality.

Figure 2. The process of modeling sci-fi gun.

3.3 Uv-mapping:

At this stage, you need to create 2D surfaces from a ready-made 3D model in order to color this surface and apply a texture to it. I was doing a scan of a low-poly model, which is easiest to imagine in the form of flat fragments. Then I selected the stitches for the incision. (see figure 3) The cut fragments remain three-dimensional, and special programs "unfold" them, turning them into planes. This is usually the responsibility of a function called Unwrap in 3D editors. The resulting fragments are distributed automatically across the editing field without overlapping each other, with the necessary distance from the edges of individual elements for further superimposing textures on different fragments. (see figure 3). After that, the process of applying color and texture, its alignment at the desired angle. At the end of the process, the scan is "stitched" back into a three-dimensional object. To achieve this goal, I used the RizomUV program.

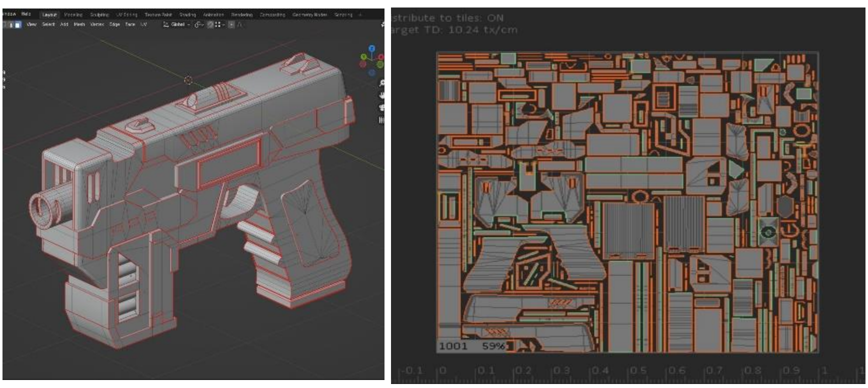

Figure 3. The process of making UV seams on the model and packing them in UV-map

3.4 Baking:

It's the turn to receive information from the high-poly model and create texture maps based on it now, which will transfer this information to the low-poly model using its UV scan. Previously, I created two versions of the same model, one high poly, and the other low poly.

Low-poly will be further integrated into the game engine. The point is to avoid loading the game environment in the future and to create a better optimization of the model itself. You can notice the difference in Figure 4. Also during baking, I baked several cards such as shadows, cavities. For this purpose, I used the Marmoset ToolBag program.

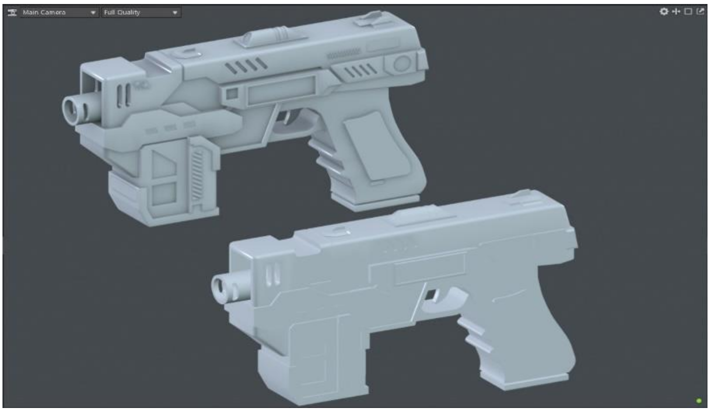

Figure 4. The difference between the low-poly model and the baked low-poly model

3.1 Texturing:

It's time for the low poly model painting stage. To do this, I used the Substance Painter program. From previously collected references, and to my personal taste, I textured the model of the pistol. The materials are based on steel, plastic and leather. For the beauty of the model, I
added the names of the gun, and its brand, and also added scuffs, dirt and dust to achieve realism.

3.2 Rendering:

Next, the final stage for me is the rendering of the model itself using light, and adding some special effects. The final result can be seen in Figure 5.

Figure 5. The final textured version of the sci-fi pistol with a specific light

4. Results and analysis:

4.1 Alpha Testing

Alpha testing was conducted by my game development team to control system errors and ensure proper integration of the model into the gaming environment. If a system error occurs in the process or in the future, it will be fixed immediately. The testing of the game asset is carried out taking into account the following aspects:

1. In order to test the 3D model, automated testing tools such as Blender's Mesh Analysis, and Unity Model Inspector were used. After the test, no problems with distorted mesh, incorrect or non-inverted normals, and low productivity were identified.
2. Testing the 3D model to check whether the created game asset meets the technical characteristics of our target platform and engine, such as the number of polygons, texture size, lighting system and shader support. The number of polygons in my model is 5355. 4k textures were used. No problems with artifacts and shaders have been identified.
3. Topology testing to check whether the model is optimized enough for further integration into the environment. The topology is relatively clean and meets the requirements. Optional triangles and polygons are avoided.
4. Testing for the correct proportion of proportions, scales and distorted shapes. To avoid these problems, reference images and measurements were used in the modeling.

5. Testing the model in various scenarios and angles, lighting conditions, and interaction with the environment. Errors, glitches, cropping, stretching, popping or flickering were not detected.
6. Testing the uv-map. The stitches were applied to the Hard Edge, and also in places invisible to the eyes. The curved polygons are aligned. No problems with distortion and distortions have been identified. The shells do not overlap. the texel density is correct. The scan was packed very compactly to avoid empty spaces and with all the rules for adding indentation at the seams. The pixel density on the texture meets the requirements of the project.

4.2 Beta Testing:

Tests were conducted to determine the suitability and evaluation of the model. Beta testing was conducted in February 2024 by interviewing 20 respondents. This test uses the Likert scale, as it is one of the most reliable ways to evaluate opinions and perceptions. There are five possible answers in the survey, such as: Completely agree, agree, slightly agree, disagree and strongly disagree. The results of the analysis are shown below:

Question 1. ”The model's polygon count is optimized for performance without sacrificing visual quality: ”

The majority of participants (15 out of 20), 75%, agreed that the number of polygons in the model is optimized to improve performance without compromising visual quality. However,
several participants (5 out of 20), 25%, disagreed with this, suggesting that further optimization may be required.

Question 2. ”The model's overall design complements the aesthetic of the game environment”; The vast majority of participants (17 out of 20), 85%, fully agreed or agreed that the overall design of the model complements the aesthetics of the game environment. This suggests that the design was successful and organically fit into the game world.

Question 3. ”The model accurately reflects the nature of the intended object”; The vast majority of participants (16 out of 20), 80%, agree or slightly agree that the model accurately reflects the intended object based on its real prototype. There were 4 people who disagree, and in their opinion, some things should be recycled

Question 4. ”The texture quality of the model is realistic and well-executed”;
The majority of participants (16 out of 20), 80%, agree or completely agree that the texture quality of the model is realistic and well executed. This suggests that the textures have

significantly improved the realism of the model and the overall quality. However, there are 4 respondents who felt that some bruises and places of dirt need uniqueness.

Question 5. ”The level of detail in the model enhances its visual appeal”; The majority of participants (18 out of 20), 90%, agreed. This indicates that the level of detail was sufficient and had a positive effect on the overall quality of the model. However, 2 people disagree with this conclusion.

Question 6. ”The model's lighting and shading effects enhance its realism and immersion”;
Most participants (15 out of 20) fully agree or agree that the lighting and shading effects of the model enhance its realism and immersion in the atmosphere. This suggests that lighting and shading have been successful in creating a compelling and immersive visual experience.

5. Conclusions

In conclusion, this work conducted a comprehensive study of the process of creating a 3D game model, starting with the fundamental principles of 3D modeling and ending with the practical implementation of ready-to-play resources. We analyzed the importance of 3D modeling in various industries and emphasized the importance of understanding the basics of 3D modeling, the critical role of topology in ensuring effective model management and animation. The modeling process was also described, from conceptualization to implementation, which provided valuable information about the creative path that artists and designers are taking, creating exciting virtual worlds. Moreover, the discussion of testing procedures and analysis techniques highlighted the importance of quality assurance to ensure the smooth integration of gaming resources into the gaming environment. During alpha and beta testing, we evaluated the performance, aesthetics and functionality of the created resources, emphasizing the need for optimization and realism to improve the gameplay.

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Шұғай Темірлан[1]
[1]SDU University, Қаскелең, Қазақстан
*e-mail: 221107049@stu.sdu.edu.kz

3D ОЙЫН АКТИВТЕРІН ДАМЫТУДЫҢ ӘДІСТЕРІ МЕН ҚИЫНДЫҚТАРЫН АШУ

Аңдатпа. 3d модельдеу саласы ойын-сауықтан медицинаға дейін және одан тыс жерлерде әртүрлі салалармен және қолданбалармен тығыз байланысты динамикалық пейзаж болып табылады. Бұл мақалада 3D модельдеудің іргелі аспектілері, оның қолданбалары қарастырылады және осы жұмыста қолданылатын әртүрлі модельдеу әдістері мен құралдарын сипаттай отырып, тұжырымдамадан іске асыруға дейінгі ойын активтерін жасау процесінің егжей-тегжейлі сипаттамасы берілген. Әрі қарай құрылған ресурстардың сапасы мен өнімділігін бағалау үшін тестілеу және талдау процедуралары жүргізілді. Бұл жан-жақты зерттеудің мақсаты - оқырмандарға 3d ойындарының үлгілерін жасау процесіндегі күрделіліктерді жақсырақ түсіну.

Түйін сөздер: визуалды эффектілер, 3D модельдеу, ойын модельдері, көпбұрышты модельдеу, топология, текстуралау, рендеринг, виртуалды шындық, оңтайландыру, визуализация

Шұғай Темірлан[1]
[1]SDU University, Каскелен, Казахстан
*e-mail: 221107049@stu.sdu.edu.kz

РАЗБИРАЕМСЯ В МЕТОДАХ И СЛОЖНОСТЯХ РАЗРАБОТКИ 3D-ИГРОВЫХ РЕСУРСОВ

Аннотация. Область 3D-моделирования - это динамичный ландшафт, тесно связанный с различными отраслями промышленности и приложениями, от развлечений до медицины и за ее пределами. В данной статье рассматриваются фундаментальные аспекты 3D-моделирования, его приложения и приводится подробное описание процесса создания игровых ресурсов, от концептуализации до реализации, с описанием различных методов моделирования и инструментов, используемых в данной работе. Далее были проведены процедуры тестирования и анализа, используемые для оценки качества и производительности созданных ресурсов. Цель этого всестороннего исследования - дать читателям более полное представление о тонкостях, связанных с процессом создания моделей для 3D-игр.

Ключевые слова: визуальные эффекты, 3d-моделирование, игровые модели, полигональное моделирование, топология, текстурирование, рендеринг, виртуальная реальность, оптимизация, визуализация

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