KEY STAGES IN THE DEVELOPMENT OF A 3D CHARACTER FOR COMPUTER GAMES

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***Abstract.** This article examines the key stages of developing a 3D character for computer games as a comprehensive technological process. It analyses the structural organisation of the character creation pipeline, including conceptual design, modelling, retopology, texturing, rigging and animation. Particular attention is paid to the optimisation of geometry in accordance with real-time requirements. Current trends in the automation of character creation processes are identified.*
***Keywords:** 3D character, game development, retopology, optimisation, rigging.*

The modern computer games industry is characterised by a high level of technological complexity and increasing demands on the quality of digital content. 3D characters are a central element of interactive systems, providing not only visual representation but also functional interaction between the user and the virtual environment. In this regard, the process of their creation requires a clearly structured approach that takes into account both artistic and engineering aspects.

An important aspect of current research is the consideration of the 3D character creation process not as a series of separate stages, but as an integrated system in which each component influences the quality of the final result [1, 2]. In particular, errors made in the early stages of modelling or retopology can significantly complicate the subsequent stages of texturing and animation, leading to increased time and resource expenditure [3]. Thus, the efficiency of the pipeline is largely determined by the coherence of all its components.

The relevance of this research stems from the need to optimise 3D models in accordance with the performance constraints of game engines, a point particularly emphasised in recent studies on adapting characters to real-time conditions [4, 5].

The aim of this work is to analyse the key stages of 3D character development and to determine their role in ensuring a balance between visual quality and computational efficiency.

The process of creating a 3D character should be viewed as a sequence of interrelated stages that form a single technological pipeline (fig. 1).

The initial stage involves conceptual design, during which the character's visual and stylistic characteristics are defined. Concept art serves as the basis for subsequent 3D modelling and defines the parameters of shape, proportions and level of detail [6].

The 3D modelling stage [7] can be implemented using two main approaches: creating a high-poly or low-poly model. High-poly modelling is typically based on digital sculpting technologies, which allow for a high level of geometric detail and the accurate reproduction of fine surface elements. At the same time, the resulting models are characterised by a significant number of polygons and cannot be used directly in the game environment due to performance limitations.

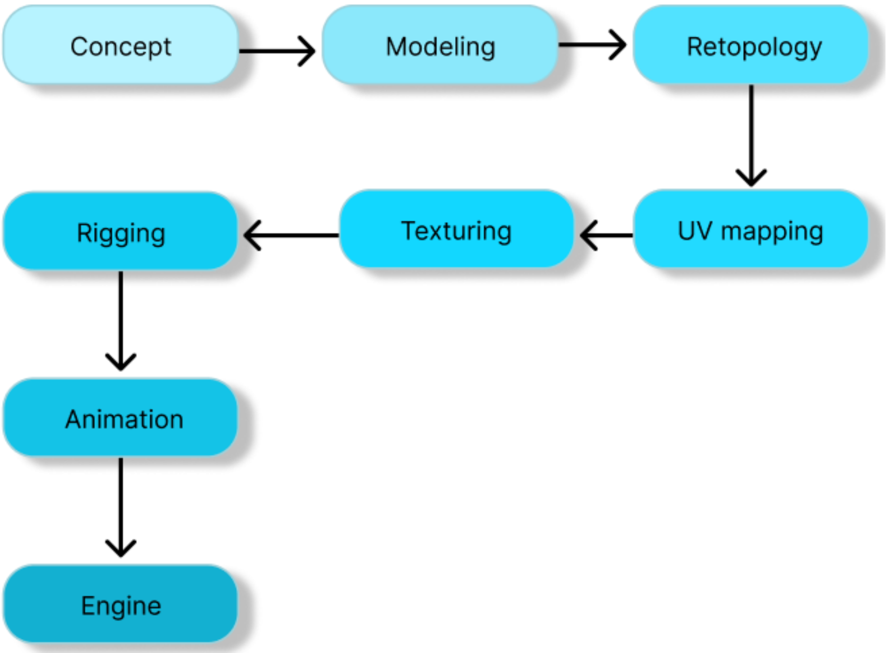

Figure 1 – The main stages of 3D character development as a pipeline

Another approach is low-poly modelling, which involves creating geometry with a limited number of polygons from the outset. This approach allows a model suitable for real-time use to be created immediately, but requires a high level of control over topology and considerable developer experience. In the practice of game character development, a combined approach is most commonly used, in which a high-polygon model is used as a source of detail, and a low-polygon model as the final optimised geometry.

It is worth pointing out that high-polygon modelling ensures artistic expressiveness of form, but this comes at the cost of a lack of control over the topological structure. Consequently, there is a need for further formalisation of the geometry, which is implemented at the retopology stage, ensuring the transition from a highly detailed model to an optimised structure suitable for use in interactive environments.

In this context, retopology acts as a key stage in geometry optimisation. It consists in the formation of a new polygonal mesh with a rational topological structure, ensuring effective deformation of the model during animation. According to recent research, the correct organisation of edge flow is a determining factor in the quality of animation and the stability of the geometry [3]. Furthermore, retopology reduces the computational load without a significant loss of visual quality, which is critically important for gaming applications [3].

Furthermore, retopology plays an important role in preparing the model for subsequent stages of the pipeline, in particular UV unwrapping and texturing. The presence of a well-organised topology significantly simplifies the unwrapping process and allows for a more uniform distribution of texture coordinates. Additionally, an optimised mesh ensures predictable model behaviour during deformations, which is critically important for real-time character animation [3].

Current investigations place particular emphasis on the optimisation of 3D characters. This involves not only reducing the number of polygons, but also the efficient use of texture memory, the application of texture atlases, and the implementation of various levels of detail (LOD). Such approaches allow the model to be adapted to different rendering conditions and ensure stable performance even on limited hardware resources [4, 5]. Another important aspect is the balance between visual quality and computational complexity, which determines the effectiveness of the character's use in the game environment.

Following geometry optimisation, UV unwrapping is performed, which ensures the correct mapping of textures onto the model's surface. Effective organisation of UV space allows for the minimisation of distortion and an improvement in the quality of texture reproduction.

The texturing stage is implemented using a physically based rendering (PBR) approach, which involves the use of a set of material maps. This approach ensures realistic interaction between light and the object's surface and enhances the visual realism of the scene.

Rigging involves the creation of a hierarchical skeletal structure that controls the model's deformations. According to scientific research, the quality of the rigging directly influences the naturalness of the character's movements and the stability of the animation [8, 9].

Animation is the finishing touch in shaping a character's behavioural characteristics. The use of both keyframe animation and motion capture technologies enables a high level of realism to be achieved [8, 10, 11].

Integrating the character into the game engine involves configuring materials, animation systems and physical parameters. Final optimisation is also carried out at this stage, including the use of levels of detail and resource compression.

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Recent research demonstrates the active development of automated approaches to character creation. In particular, the use of neural networks allows the process of rigging and generating skeletal structures to be automated, which significantly improves the efficiency of the production process.

The result of the study established that the key challenge in developing 3D characters is to strike a balance between visual quality and real-time performance, which is achieved by optimising each stage of the production process. In particular, a high level of detail is established during the high-poly modelling stage, after which it is adapted to the requirements of the game environment through retopology and a reduction in polygon complexity, as well as the transfer of details to texture maps.

In indie development practice, balance is achieved through the use of simplified geometry and universal tools, which minimises the resource requirements of production. In AAA projects, multi-level optimisation is employed, involving the creation of multiple levels of detail (LOD), the use of normals and other maps to simulate complex geometry, and the distribution of functions across specialised tools. This approach ensures high-quality visualisation whilst maintaining stable performance of the game systems.

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