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Graphics Technologies and Next-Generation Games in the Last 10 Years

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Abstract: Electronic games represent a very important application for computer technology, especially for graphics technology, in which games play a pioneering role. Many new graphics technologies have emerged from the electronic game industry. This paper collates graphics technologies closely related to the game industry and presents an overview of its critical development trends.

1. Introduction

Electronic games are becoming more popular and have a strong connection with computer graphics. In the contemporary digital society, video games are a significant part of the transformation in technological culture [1]. The concept of next-generation games was developed by the game industry decades ago. From a gamer's point of view, the next-generation games are about higher-quality graphics, higher-quality effects, and more realistic scenes. The most important contributor to the modern game industry is graphic technology.

This report introduces background information about the current state of game development and the game industry and takes game industry China as an example. In the development part, this report first focuses on 2D animation technology and takes Live 2d as an example and introduces its workflow, application, and its strength and weakness. An improvement method about segmentation is also covered. Then, PBR and raytracing technology will be introduced and explained as examples in 3D rendering technology. Finally, this report will have a summary and discuss the relationship between graphics, gameplay, and culture.

2. Background Information

Electronic games have become an indispensable part of modern life, a medium for many cultures. The evolution of electronic games has entered a new phase, the next-generation game. In Technologies Between Games and Culture [1], the author said that “The need to engage with video games on this basis is enduring and, we would argue, increasing [1].” Over the last 10 years, graphics technologies related to video games have evolved and the gaming industry is expanding quickly.

China is a great example of quick growth in the game industry. Tencent, NetEase, Perfect World, and 37 Interactive Entertainment were in the list of the top 25 global game revenue in 2018 [2]. In 2019, the sales volume of domestically developed games in the overseas market increased by 21%, reaching $11.59 billion [2]. MiHoYo, a growing Chinese game company, published a framework based on deep learning for semi-automatic garment animation at SIGGRAPH ASIA in 2019 and contributed to the graphics [3].

3. Development

3.1. 2D animation Technology

3.1.1. Live 2D

Live 2D is a typical 2D animation technology created by Tetsuya Nakajo. In 2011, Live 2D software received attention after the "O.I.U." system, which derived from Live 2D, being used for the first time in the PSP game, Oreimo Portable, developed by Bandai Namco Games [4].

Live 2D is usually used to generate 2D animations, especially anime-style characters. Figure 1 is a flow chart of the workflow of Live 2D. As a first step, the illustrator needs to provide character illustrations. After that, the illustration needs to be broken down into layered parts, such as eyes, mouths, arms, etc. Then, those continuous parts will be rigged to a skeleton. Finally, they are assembled into animated characters.

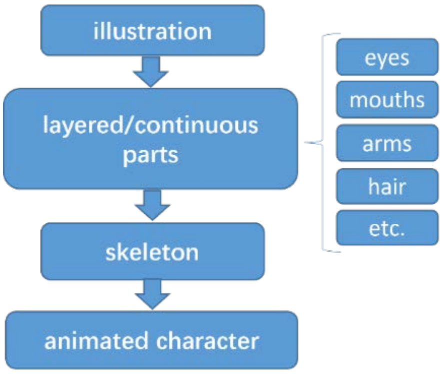

Figure 1: Live 2d’s workflow

In the actual application, developers also need to track movements to complete the animation by combining Live 2D with motion capture technology. Besides video games and visual novels, this combination is also used for Vtuber streaming. Although 3D animation technologies such as Cel shading or Toon Shading can render 3d models to 2D effect, Live 2D, as a pure 2D method, still has its advantages. Developers don’t need 3D modeling because Live 2D only uses 2-dimensional translation, rotation, deformation. Also, Live 2D is easy to use and can have a good animation effect for portable devices at a low cost. Based on the feedback from the market, Live 2D is well received by gamers. But the limitation is obvious: Characters can't turn around because it is based on 2D illustration, and it is not easy for developers to segment illustrations.

3.1.2. Interactive Edge-Aware Segmentation [6]

In general, the segmentation of illustrations and the skeleton binding are time-consuming. Recent research on the improvement of segmentation methods has been brought out by University of Tsukuba: Interactive Edge-Aware Segmentation and this method is based on an existing method, Lazy-brush [5].

The method’s first step is edge enhancement by employing HE (Histogram Equalization) and

LoG (Laplacian of Gaussian) filter [5]. The basic idea of Histogram Equalization is to broaden the gray level with more pixels and compress the gray level with fewer pixels. Hence, the dynamic range of pixel values is expanded, and the image will be clearer. Laplace operator is an edge detection operator. It completes edge detection by differentiating an image. A sensible reform would be using a Gaussian convolution filter before edge detection of the Laplace operator to reduce the image noise because the Laplace operator is sensitive to discrete points and noise.

Hence, users can draw body-part boundaries easily. The method takes the end line between endpoints of each user-specified body-part boundary as the diameter then calculates a circle [4]. The overlaps between adjacent body parts are the intersection of the circle and body part segment [5]. From Figure 2 [5], we can see that Interactive Edge-Aware Segmentation is more effective than traditional segmentation techniques for character illustrations.

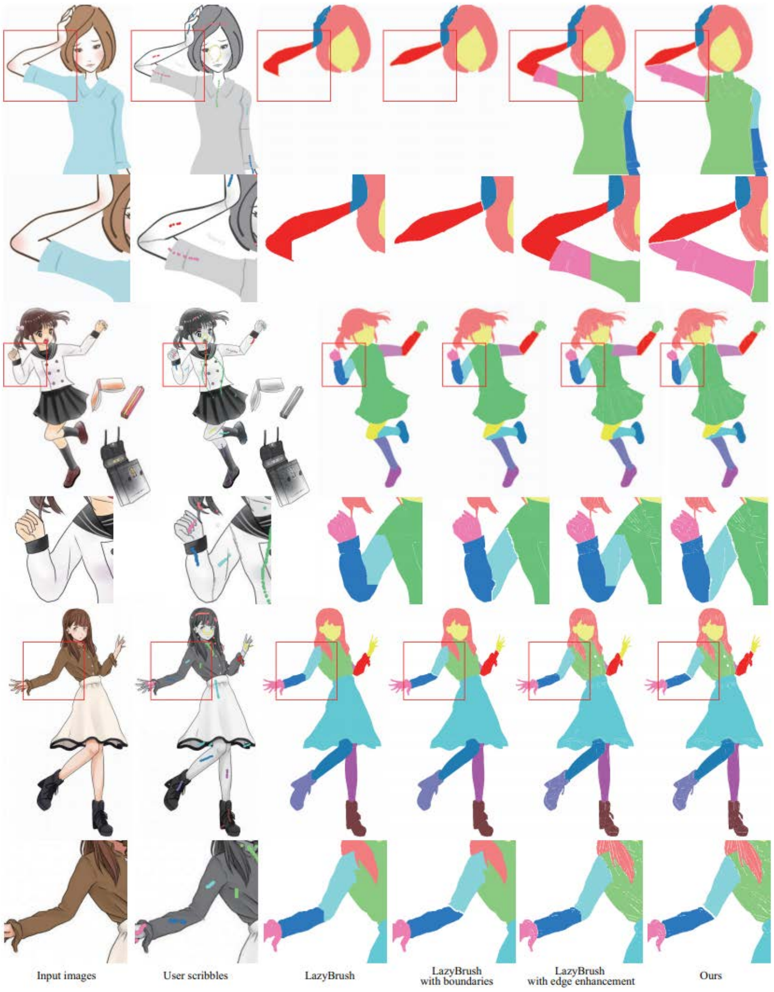

Figure 2: Result comparison of Interactive Edge-Aware Segmentation and the conventional technique [5]

As gamers' desire for better game graphics is not limited to 3D games, 2D animation technology is still evolving. The application of 2D animation technologies, such as Live 2D, is the innovation of traditional frame-to-frame animation.

4. 3D rendering Technology

4.1. Physically-based Rendering

PBR (Physically-based Rendering), based on the principles and theories of the physical world, is a rendering system relying on computer hardware and graphics API. PBR supports more complex material features than conventional methods, such as Fresnel diffraction, metallicity, translucent materials, etc.

PBR is a multi-disciplinary system. It has been developed from the Lambert-Lighting for years, during which there have been many iterations of improvement. There have already been studies into the feasibility of this technology. According to a report published in 2006, Verification of Physically Based Rendering Algorithms, various methods had been introduced to verify the implementation of PBR experimentally [6]. "The groundwork in this field has been well laid [7]", the report said. Even in the field of computer displays, there were attempts to use BRDF to display materials. The prototype in Dynamic Display of BRDFs [8] was based on a liquid surface and met the criteria for a BRDF (Bidirectional Reflectance Distribution Function, describing the relationship between the incident and reflected light on a surface) display.

In 2012, Brent Burly, an engineer who worked for Disney Animation Studios, gave a lecture named "Physically Based Shading at Disney" in ACM SIGGRAPH Courses [8]. He put forward the Disney Principled BRDF [8], which set the direction and standard of PBR for the games and films after. The Disney Principled BRDF is an art directable lighting model rather than a physically correct one. It simplifies the previous parameters and workflow of PBR with a few easy-to-understand parameters and a highly developed art workflow. Since Disney introduced Disney Principled BRDF in 2012 [8], it had caused a sensation in the game and film industry. Subsequently, many influential game engines, renderers, and modeling software had their implementation of PBR based on Disney's principle. From 2013 to 2015, Unreal Engine 4, Unity 5, Frostbite, and Cry Engine 3.6 successively supported this PBR technology.

After a long time of development, PBR technology is becoming more realistic, more complex, more economical, and more comprehensive. It is the next-generation rendering technology in computer graphics and is applied both in real-time rendering and offline rendering. PBR has been widely used in today's games: PC games, mobile games, console games, etc, providing game developers with an overall framework to improve visual effects. Most gamers have already experienced the charm of this next-generation technology. Except being applied in the game and film industry, PBR also contributing to computer-aided design, computer-aided manufacturing, virtual reality, visualization of scientific computing, etc.

4.2. Real-time Raytracing

Rasterization (This report will not cover the rasterization algorithm. In simple terms, rasterization is the process of transforming geometric information into an image formed by grids.) has become the approved and conventional method for rendering 3D images for decades. However, rasterization can not process global effects well. In situations such as soft shadows, glossy reflection, and indirect illumination, light bounces more than once so that physical accuracy cannot be guaranteed by rasterization. Then came the raytracing technology. Both rasterization and raytracing have significant advantages and disadvantages. Rasterization is fast, but the quality is relatively low. Raytracing is physically accurate, but its calculations take a long time. In general, rasterization is more suitable for real-time rendering, and raytracing is mainly used for offline rendering.

The very original algorithm of raytracing, the Pinhole Camera Model, is based on this optical abstraction (Although this is not how light travels in the real physical world): Light rays travel from the light sources to the eye or camera in straight lines and do not collide with each other. Also, according to raytracing algorithms, light paths are considered to be reversible. Hence, the most important idea is to think of the camera or eye and the light source as geometrical points, and the light comes from the camera rather than the light source. Figure 3 [9] is a diagram for a simple model of raytracing.

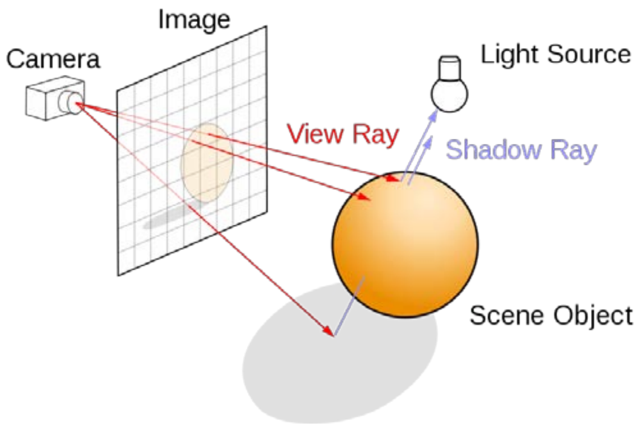

Figure 3: Raytracing diagram

View ray starts at the camera and goes through a pixel on the image plane. The view ray, if it can hit the scene object, will intersect the surface of the scene object, and geometrical intersection points (real and positive roots) can be solved by the following equations:

$$\text{Ray:}\ \ \vec{r}(t) = o + t\vec{d},\ \ 0 \le t < \infty$$

$$\textit{General implicit surface:}\ \ f(\vec{P}) = 0$$

$$\textit{Substitute ray equation:}\ \ f(\vec{o} + t\vec{d}) = 0$$

The raytracing algorithm will choose the closest scene intersection point. A shadow ray can be determined between this intersection point and the light source. With the view ray and the shadow ray, the raytracing algorithm can perform shading calculations at an intersection point to compute the color of a pixel in the image plane.

Real-time raytracing technology was first exposed at GDC 2018 and has attracted a lot of attention. “Real-time raytracing has been a dream of the graphics industry and game developers for decades [9]”, said Tony Tamasi, the senior vice-president of Nvidia. In the same year, Microsoft announced DXR(DirectX Ray Tracing), and NVIDIA published the new GPU architecture, Turing, which can speed up raytracing, as well as the RTX series of graphics cards with real-time ray-tracing technology [9]. Also in 2018, Battlefield V, based on EA's Frostbite, became the first game to use Hybrid Ray-Traced Reflections. In 2019, DirectX Raytracing had become so ubiquitous that most players can enjoy an upgrade to their gaming experience thanks to Nvidia’s latest driver which unlocked ray tracing on lower-priced GeForce GTX graphics cards [9].

5. Conclusions

From frame-to-frame animation to Live 2D, from rasterization to real-time raytracing, graphics have come a long way, which is beneficial for games development. 2D animation technology is developing well due to the growing popularity of Otaku culture originated from Japan and independent games such as Hollow Knight. In 3D rendering, the current main research interest is physical accuracy. However, the relationship between graphic technology, gameplay, and culture is also worth noticing.

Serving for gameplay, the content of games, graphics are one of the techniques of expression. Games can be used as a form of entertainment or artistic expression, and allow players to be involved both culturally and collectively [1]. This brings out the complexity of becoming intertwined with technological development lineages [1]. Nowadays, different games have different content and require different techniques of expression due to the development of technology and art. Renderings of different art styles are more common. As technology, gameplay, and culture are becoming more mixed with each other, more modern technologies and cultural concepts are being applied to game development. It is optimistic that the game industry will become more diverse in the future.

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