Visual Computing: Cell Shading

***Abstract*— Cell shading is a type of non-photorealistic rendering, this shader type involves setting specific shadow and light parameters, based on which these go from a more realistic look to a more abstract and simplified style, flattening the color gradients in an attempt to create a 2D look in a 3D space. This can also result in lighter resource consumption when it comes to rendering these graphics, as well as a visual style that doesn't show its age as much due to its non-realistic approach.**

***Index Terms*—3D, 2D, Rendering, Performance**

I. Introduction

Cell shading is a way of 3D rendering that has been growing in popularity over the years, this due to its similarity with comic books and Japanese manga styles, attempting to recreate it's more hand drawn flat look by changing how lights and shadows are displayed, drifting away from color ramps and gradients, and into more solid blocks of color to represent dimension.
The name of this non-photorealistic rendering style derives from celluloid, a material commonly used to make hand drawn animation. [4]

This technique started to surface in the late 90s, being prominently showcased in Japanese anime, and then expanding into other areas and media such as video games. The technique grew ever more in popularity as 3D technology grew and improved in quality, becoming an increasingly more sustainable way to approach animation. [3]

In the game development industry, the first implementation of Cell Shading was seen with the game Jet Set Radio for the Sega Dreamcast, which managed to win multiple awards for its visual presentation.

Fig. 1. Jet Set Radio-InGame Screenshot. [7]

This visual style was then replicated throughout the years in prominent Titles such as Dragon Ball Z, Guilty Gear, and The Legend of Zelda: The WindWaker, a game which set the Zelda franchise on a new path as most sequels that were released afterwards adopted the Cell Shading style up until this very day, with the release of The Legend of Zelda Tears of the Kingdom.

Fig. 2. WindWaker-InGame Screenshot. [11]

The Cell shaded look has been used more and more over the years, being a staple in some genres, such as anime styled games, which try to mimic their 2D counterparts. Becoming some of the most well-known games in current times, such as Genshin Impact, or the Persona Series, where the technique has been more and more refined, not only relying on the shader to cast shadows, but also having a lot of texture work, to in a way, fake highlights and shadows that simulate sub surface scattering. This technique tends to work simultaneously with the shader, its *contact shadows*, as well as the *Fresnel* effect that casts rim light like effects, to achieve the desired 2D look.

Fig. 3. Genshin Impact-InGame Screenshot. [10]

II. COMPARISON IN BETWEEN SHADERS

A. Conventional Shaders

In more conventional shaders, where photorealism is the priority, lighting is calculated in such a way, where the cast shadows' values result in a gradient in between the lit areas and shaded areas of models.

Conventional Shader Features:

- Photorealistic Lighting
- Color Ramps/Gradients
- High Resource Consumption while Rendering
- Can seem Outdated overtime as Tech Advances

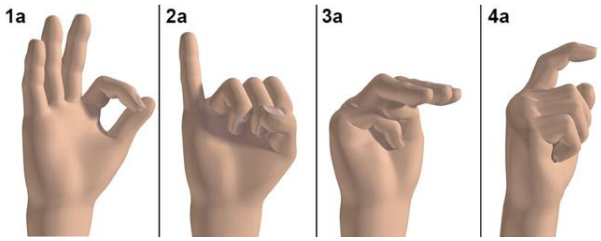

Fig. 4. Conventional Global Illumination. [1]

B. Cell Shading

Cell shading differs from conventional shaders, in the sense that it isn't photorealistic. Essentially, instead of having a gradient going from a lit surface to a dark one, those values are clamped, leaving hard breakpoints between the lit areas and the shaded ones, giving objects a more cartoon-like look.

Cell Shading Features:

- Clamps Color Values into *Blocks* of Color
- Simulates a Cartoon-like Style
- Lower Resource Consumption while Rendering
- Ages Gracefully due to being Stylized

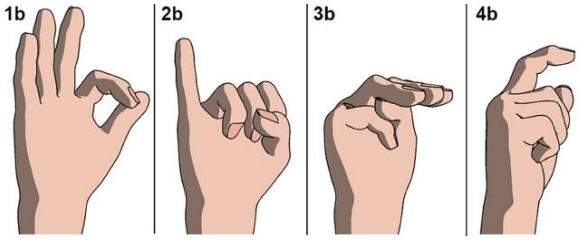

Fig. 5. Cell Shading. [1]

III. ACHIEVING A 2D LOOK

To achieve this cell shaded look, a lot of aspects need to be utilized and tweaked, namely how *normals* are perceived when facing the camera to define which parts of the models are lit and which are in shadow, outlines depending on the desired art style, *Contact Shadows* to add simulated shadows cast by other parts of the model, on top of the ones created by the *normals* perception. ("a normal is an object (e.g. a line, ray, or vector) that is perpendicular to a given object " [5])

A. Normals affecting shadow generation

In a 3d object, each of its normals face a direction perpendicular to how that polygon is generated in space. *Normals* that face the camera are perceived as lighter, whilst *normals* that don´t, are perceived as darker in set increments. The number of these different shading tones can also be defined. *Normals* that are at 90º can also be used to cast rim lights or shadows. [3]

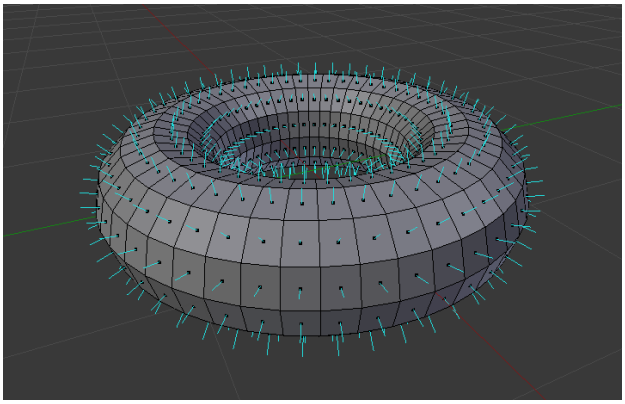

Fig. 6. Direction of Normals in a 3d object. [9]

B. Outlines

Edge detection can be used depending on the style the artists are going for to create outlines on their models. This is done by a mathematical process that defines curves and changes the brightness of those areas to create the effect of an outline. [3]

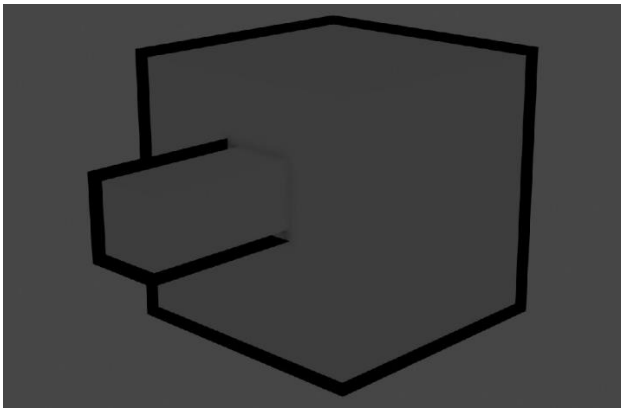

Fig. 7. Showcase of Outlines in a 3d object. [8]

C. Contact Shadows

Contact shadows may be utilized to simulate how some shadows are projected into the model, functioning as an addition on top of regular shadows that are dynamically cast. Although these are not calculated in the same way as they are a screen space effect. These can also result in stranger outcomes depending on the camera angle, as the shadows will sometimes adopt unnatural forms. [6]

Fig. 8. Showcase of Contact Shadows in a 3d object. [6]

D. Texturing

When it comes to Cell shading, as described in the previous methods, multiple techniques are used to properly shade objects. After having the shader configured, some shadows can also be directly painted onto the object's textures. These won't be dynamic as the other shadows, but because of this, they can be used to properly define certain key aspects of the model. [2]

Fig. 9. Showcase of Shadows Baked into the Texture of an object. [6]

I V. UTILITY OF CELL SHADING

With all of this in mind, it's understandable how this type of shading is being used to bridge the gap between media. 2D animation also has its limitations, namely with camera angles and complicated motions of characters and scenery. These being much more viable to recreate in 3D space, as such, some of these scenes and backgrounds are made in this fashion, utilizing cell shading in an attempt to blend these media into a cohesive composition.

Beyond being a useful tool in 2D animation itself, it has also become a method to transport projects from one media type to another, while still maintaining its visual style, and remaining true to its source material.

Furthermore, as computer generated graphics and visual computing evolves, the aging of photo-realistic graphics can become very noticeable. Cell Shading on the other hand, due to attempting to simulate Cartoons and Japanese manga/anime, is a style that hides the featured media's age, as is evident with some of the major titles mentioned in the article, such as The Legend of Zelda: The Wind Waker, which released in 2002, whose visuals still hold up elegantly to this very day.

V. CONCLUSION

Cell shading ends up being a unique way of rendering 3D graphics, that can not only help with performance when comparing to conventional global illumination, but also conserve its visuals through time as the video game landscape evolves.

It also proves to be an interesting and viable method to bridge the gap between media, making it possible to blend 3D objects into 2D space in a much less intrusive way.

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