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Efficient Rendering Analysis for Converting 3D to 2D Cartoon Style

Tingkai Hu

Stony Brook Institute, Anhui University, Anhui, China

TingkaiHu@cqu-edu.cn

Abstract. This paper explores using non-photorealistic rendering (NPR) techniques in Blender to simulate a 2D cartoon aesthetic using 3D models. NPR has become increasingly helpful in various fields like animation, education, and games due to its special aesthetic style, which resembles 2D animations and is low-cost. This study investigates how NPR, including flat shading and tone flattening, can be applied in Blender to build an efficient and wonderful NPR workflow. A toon shader pipeline is constructed using Blender's node system on the material page of Blender. Specifically, the method involves many nodes in Blender, for instance, Diffuse Bidirectional Scattering Distribution Function (BSDF), Shader to RGB, ColorRamp, and Emission Shader nodes, which could help people create a stylized 2D effect on a 3D model. An experiment is conducted on an ice cream model that the author made to test the performance of this system. The result shows that this method can produce clear, visually appealing models with strong color contrast and cartoon-style aesthetics. At the same time, the approach simplifies the light environment and converts it to color bands, which is very efficient. However, it will also cause the loss of some geometric information in complex shapes, such as glass cups or objects like cars or motors. This method offers a practical solution for 2D stylized rendering and opens up the potential for applications in 3D to 2D animation, education, short video design, and conceptual art.

Keywords: Toon Shader; Non-photorealistic Rendering; Flat Shading; Tone Flattening.

1. Introduction

Over the past decade, the visual boundary between 2D and 3D animation has gradually faded. Although 3D animation has become the industry standard due to its versatility and realistic capabilities, the visual attraction of 2D animation continues to appeal to audiences. This appeal has led creators to adopt a hybrid technique, using 3D tools to produce content that visually resembles hand-drawn 2D animation. Often referred to as 3D to 2D animation, this approach relies drastically on non-photorealistic rendering (NPR) techniques to achieve.

Unlike conventional rendering methods focusing on replicating physical light and surface textures, NPR emphasizes abstraction, simplifying detail, and using color in a more cartoon style. One of the earliest influential models in this field was developed by Gooch, who proposed a lighting method designed to enhance warm-cool shading rather than simulate nature [1]. Building on such foundations, Kyprianidis mapped out a broad classification of NPR strategies, including edge enhancement, tone flattening, and painterly filters, offering a comprehensive view of stylization methods used in static and moving images [2]. Blender is a 3D generation software that has become a flexible platform for NPR experiments. Its engine enables customizable edge rendering because the Toon Bidirectional Scattering Distribution Function shader provides a cel shading function. More tools (e.g., Grease Pencil) allow 2D elements to be drawn and added directly into 3D space, so both 3D and 2D techniques can be used. These developments have made Blender appealing for artists to create 3D to 2D animations.

Researchers have also proposed algorithmic techniques that simulate painterly output using 3D models. For instance, Shiraishi and Yamaguchi introduced an approximation method to imitate the human brushwork [3]. Winnemöller focused on simplifying video content, generating stylized animation with reduced detail while maintaining motion consistency [4]. Kumar emphasized the importance of structural coherence when applying abstraction [5]. Several NPR methods have been

explicitly adapted in Blender. Zhou and Chen proposed a practical rendering pipeline strategy in Blender, incorporating toon shading, line detection, and post-processing to achieve 2D aesthetics from 3D models [6]. Kalogerakis contributed practical line extraction algorithms that enhance stroke consistency and clarity in stylized renderings [7]. Moreover, the Blender Foundation's experimental projects have demonstrated the expressive capabilities of NPR, particularly through Grease Pencil-based storytelling [8].

This paper investigates applying NPR techniques in Blender to develop a 3D animation that visually resembles traditional 2D animation. The project involves modeling, rigging, and animating, followed by implementing stylized tools such as cel shading, freestyle contour rendering, and composite filters. The goal is to implement these tools and techniques to create a 3D to 2D style tree. To test whether these methods could be helpful or not.

2. Methodology

This study primarily investigates how NPR techniques in Blender can be used to make 3D models visually resemble traditional 2D cartoons. The methodology is divided into three key components. As shown in Fig. 1, this paper will first review existing research to assist the author in understanding how NPR has evolved and how it achieves the hand-drawn aesthetic in 3D environments. This includes introducing key concepts like toon shading, freestyle edge rendering, and stylization through texture mapping. Representative examples from works such as Ghibli-style fan projects and Gobelins' student films are referenced to show how NPR has been applied. Second, the study dives into practical examples in Blender. This paper will create a 2D-style ice cream using these flows in Blender. Using the Shader Editor in Blender, this paper could build custom toon shaders based on the Shader to RGB node, cooperating with ColorRamp and Diffuse Bidirectional Scattering Distribution Function (BSDF) to produce flat colour bands. Linework could be created by using the Blender Freestyle rendering engine. The Blender Freestyle rendering engine could control the line thickness, colour, and other parameters like visibility. Finally, here are several test scenes. For example, some restaurants create cartoon characters to attract customers who like 2D animations. Other people may use this technique (NPR) to create 2D animation characters and put them on advertising boards to appeal to the people who pass by and make them notice these boards. This paper will create a 2D-style ice cream with three ice balls on the glass cup so people can put this ice cream on their advertising board or collect it as part of their collection.

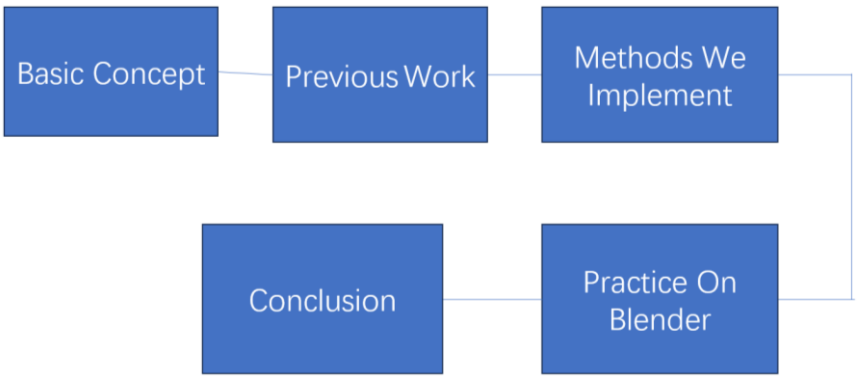

Figure 1. The pipeline of the study (Picture credit: Original).

2.1. Overview: Foundational Research and Inspiration

NPR has long aimed to simulate the hand-drawn feel within 3D environments. It seeks to go beyond photorealism, offering expressive, stylized 2D-style animation. One of the earliest and most influential contributions came from Gooch et al., who introduced warm-to-cool shading, which intentionally deviates from physically precise light simulation to produce more emotionally expressive renders [1]. Their work opened the door to a new way of thinking about shading, favoring clarity over realism.

Building on this foundation, Kyprianidis et al. proposed a widely cited taxonomy of NPR techniques, including edge enhancement, tone flattening, and painterly filtering [2]. These methods clarify the definition of NPR and lay out a structured framework that developers and artists could follow when designing stylized 3D animations. Their research has been a valuable reference for NPR applications in academic and commercial production.

On the technical side, several notable implementations have been done already. Here are some implementations on open-source environments like Blender. Zhou and Chen proposed a practical rendering pipeline that combines toon shading, line detection, and post-processing effects, showing how stylized 2D visuals can be generated directly from 3D models [6]. Their approach integrates with Blender's shader node system, which makes it more accessible for artists without advanced programming skills. Additionally, Kalogerakis et al. introduced stroke extraction algorithms that maintain consistency of edge lines, a crucial feature for 2D styled animation rendering [7].

These prior works provide the foundation of this study. As shown in Fig.1, this research follows a clear progression, from understanding basic concepts, surveying influential works, implementing specific methods, and finally applying them in Blender. While the core of this paper focuses on shader-based NPR implementation on Blender, it combines the previous research, such as toon shading or flat shading. The intention is to build this work, the ice cream model, and test a general, more practical pipeline for producing 2D-style imagery using modern 3D tools.

2.2. Shader Pipeline Integration in Blender

This paper built a stylized toon shading pipeline directly inside Blender. The whole setup was done using the Shader Editor, where each node plays a role resembling that 2D cartoon look. The goal was to recreate a particular animation style and verify whether this combined method is practical.

2.2.1. Diffuse BSDF for Flat Color.

The first step was choosing a base shader. This paper used the Diffuse BSDF, which is pretty simple; it removes specular highlights and makes everything look matte [1]. That’s precisely what this NPR needs, because reflective materials tend to break the illusion of 2D. With this shader, this paper could mimic flat surface colors without any metallic shine or realistic shading. It’s clean and works well with stylized models like the low-poly ice cream. Since the project focuses on simple shapes, keeping the base as flat as possible helps set up the cartoon style appearance.

2.2.2. Shader to RGB + ColorRamp for Creating Light Bands.

Once the flat base was ready, this paper needed a way to add light and shadow in an animation style. Hence, this paper uses the Shader to RGB [6]. This node converts Blender's internal light data into color values, which can then be edited using the ColorRamp, another node in Blender [2]. This paper used this flow to create bands of light and dark. The result is more graphic, less real, like the classic 2D animation or games. The author tried a few settings and found that the color changes suddenly rather than steadily. This approach is directly inspired by Kyprianidis et al.’s “tone flattening” technique. And people can make it soft or dramatic by moving the sliders in ColorRamp.

2.2.3. Emission Shader for Stylized Output and Control.

After adjusting the light, this paper connected everything to an Emission Shader instead of using the default output from BSDF, which people commonly used [6]. Because Emission could ignore Blender's scene lighting and show pure color, this Emission system could generate an excellent cartoon-style model. And it could also make it easier to control this model, rather than having some weird shadows or unexpected highlights. Because everything that appeared in the render was directly shown on the thesis shader setup. This part closely follows the NPR workflow mentioned in Zhou and Chen’s paper. They show that emission shading can be very predictable for stylized work. In this paper’s test renders, this setup keeps things very clean and lets the author focus only on artistic creation instead of fixing light bugs brought by the standard shader system.

2.3. Application Analysis

To test how well this toon shading pipeline works, this paper built a 3D scene: a glass bowl with three scoops of ice cream and a small chocolate cone on the top of the cup. The model was perfect for trying stylized shading. After setting up the shader nodes, this paper rendered the scene using the flow mentioned before. The result looked more like a work from a hand-drawn animation rather than a typical 3D render with a realistic style. People could see the color bands on the ice cream surface, and this ice cream also lacks realistic reflection, making the model feel clean. Hence, people could put them into advertising for ice cream or some cartoon on television.

This workflow also has a lot of other real-world practices. For example, in children's educational videos, bright colors and simple shapes like this make it easier to grab attention and explain things vividly. In short video platforms like TikTok, fast rendering is efficient for podcasters to generate small videos and put these into their shows. It's also great for developing independent games, especially those that use a cartoon style. Developers can design and create their worlds without understanding complex lighting systems or high-quality hardware. Lastly, concept artists can use this approach to help them imagine their desired art. Compared to traditional PBR workflows, this toon shading method is faster, cheaper, and easier to control, and it could mimic the hand-drawn style perfectly.

3. Discussion

As mentioned before, this paper aimed to explore how Blender's shader system can simulate a cartoon-like 2D visual style. The example is a simple 3D model of an ice cream dessert, consisting of a low-poly glass bowl with three scoops of ice cream and a chocolate cone. The model is visually plain and lacks some fancy styles without shaders (see Fig. 2).

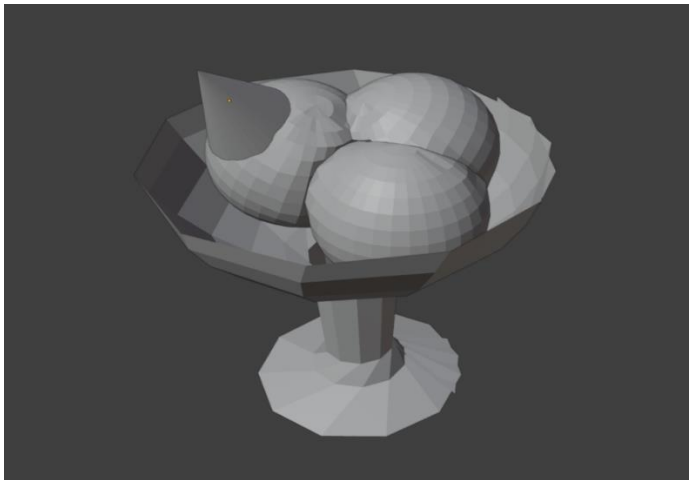

Figure 2. The original model in Blender (Picture credit: Original).

Then the paper adds the toon shading pipeline, consisting of Diffuse BSDF, Shader to RGB, ColorRamp, and Emission Shader. The model is changed. The result shows strong color contrast, visible color bands, and a flattened lighting style resembling 2D animations. The glass bowl, though in appearance it looks almost the same, appears softer and has a more abstract outline, while the ice cream scoops display strong color separation. This effect gives the render a smooth and unrealistic style compared to conventional 3D rendering (see Fig. 3).

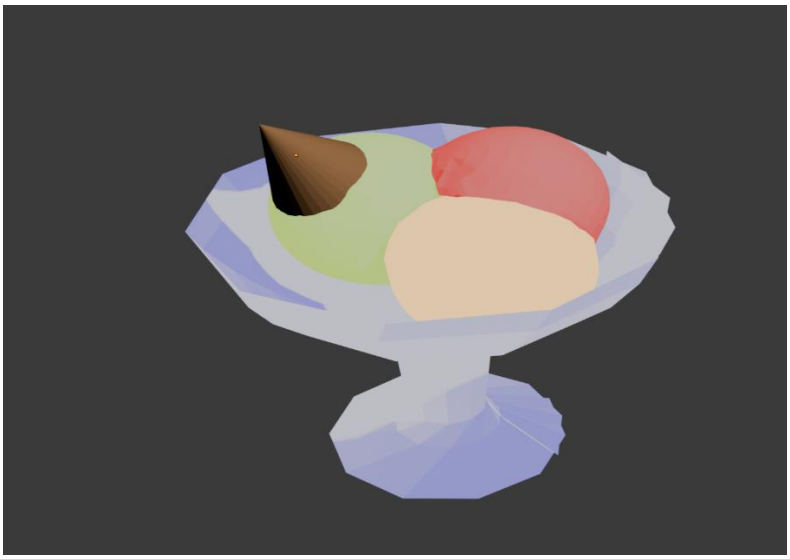

Figure 3. The model after rendering (Picture credit: Original).

The shader network was simple to construct and efficient to render, making it suitable for low-resource environments like quick video making. Look at Fig. 4, the Shader to RGB and ColorRamp pair allowed control of light banding [6]. The Emission Shader made the color output unrelated to Blender's default lighting system, forcing it to generate color. This gives the render a clean and controlled appearance that is well-suited to non-realistic rendering. This paper also uses the Freestyle line set to consistently maintain the line on the edge [7].

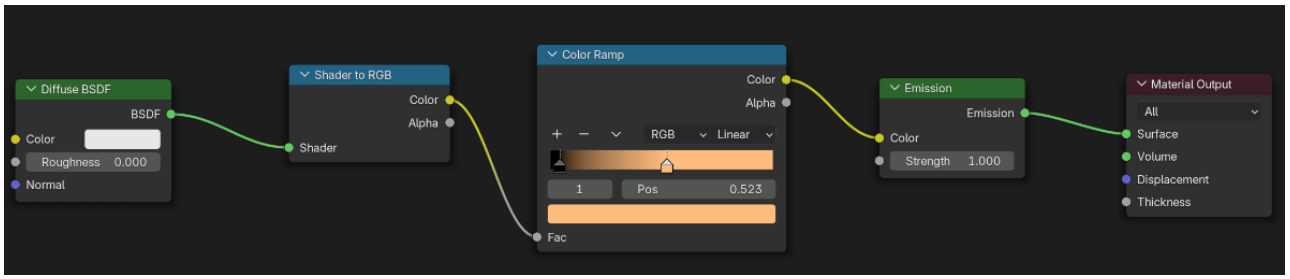

Figure 4. The rendering workflow in Blender (Picture credit: Original).

Despite its benefits, this system has some limitations. The render system tends to flatten the model, and key object features may lose clarity at some angles. For instance, in the final render, the cup of ice cream loses some of its 3D form, and it becomes less obvious that it's a little cup. In more complex scenes, this could reduce the model's special characters.

All in all, the method is fast, flexible, simple, and practical. It could handle unrealism or animation shading challenges particularly well. Hence, it has been used frequently in the animation field.

4. Conclusion

This study introduces a practical approach to achieving 2D cartoon-style rendering using Blender's NPR techniques. The goal was to explore how stylized shading methods can be applied to 3D models to simulate the visual characteristics of hand-drawn 2D animation. A toon shading pipeline was proposed to achieve this goal. The process involves Diffuse BSDF, Shader to RGB, ColorRamp, and Emission Shader in Blender. These components produce strong contrast, visible color bands, and a flattened lighting style. An ice cream model was created to test this method. Results show that this method can generate clean, expressive renders with strong colour contrast and cartoon-like aesthetics. However, it also has limitations regarding clarity and accuracy for complex materials, such as some furniture. In the future, the research will focus on improving the ability to enhance the clarity of the model by combining this pipeline with more techniques, such as Freestyle edge rendering or AI-based techniques. The goal is to develop a more competitive system for 3D-to-2D animation.

References

[1] CAI Qiang, et al. Image neural style transfer: A review. Computers and Electrical Engineering, 2023, 108: 108723.

[2] MALI Shruti Atul, et al. Making radiomics more reproducible across scanner and imaging protocol variations: a review of harmonization methods. Journal of personalized medicine, 2021, 11 (9): 842.

[3] ZOU Zheng Xia, et al. Stylized neural painting. Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition. 2021, 15689-15698.

[4] HAJIANFA Ghasem, et al. Impact of harmonization on the reproducibility of MRI radiomic features when using different scanners, acquisition parameters, and image pre-processing techniques: a phantom study. Medical & biological engineering & computing, 2024, 62 (8): 2319-2332.

[5] KUMAR MP Pavan, et al. Structure-preserving NPR framework for image abstraction and stylization. The Journal of Supercomputing, 2021, 77 (8): 8445-8513.

[6] CHEN Ying Shu. Exploring Neural Stylization and Rendering Across 2D and 3D Visual Modalities (Doctoral dissertation, Hong Kong University of Science and Technology (Hong Kong)). 2024, 1-24.

[7] KIM S G, et al. Advanced adaptive feed control for CNC machining. Robotics and Computer-Integrated Manufacturing, 2024, 85: 102621.

[8] BLENDER Open Project Team. Cartoon Rendering and NPR using Grease Pencil in Blender. Blender Foundation Whitepaper. 2019, 1-9.