Making objects and scenes look less pristine in Computer Graphics

I declare that this work is my own.

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Introduction

Realism in computer graphics encompasses various dimensions, from photorealism to behavior realism and interaction realism. In this research study, we narrow our focus to a specific facet of photorealism — the quest to make rendered scenes look less pristine. The exploration delves into the intricate world of texture-mapping approaches and their role in introducing imperfections to enhance realism.

Let's delve into the elements that contribute to reducing the pristine quality of real-world images: factors like accumulated dust, distinctive markings, the effects of wear and tear, instances of oxidation, the presence of rust, human-drawn graffiti, and numerous other imperfections. Below, we observe several images captured from real-life scenes. Among them is Figure 1, which clearly shows a graffiti drawing on a worn-out pole. Analyzing this image uncovers the elements responsible for its diminished pristine quality. Unlike the digitally created pole, this one has visible signs of paint damage and is covered in poorly done graffiti.

Moving on to Figure 2, it showcases a street road that diverges from perfection; its surface isn't uniformly flat but rather exhibits its own character with an uneven texture composed of various types of bricks and scattered fallen leaves. This textural diversity contributes significantly to reducing the scene's pristine appearance.

Lastly, Figure 3 directs our focus to the wrinkles and dirt on clothing. This image emphasizes the natural imperfections seen in everyday attire, reinforcing the pursuit of realism. The inclusion of wrinkles and dirt on the clothes adds authenticity to the scene, illustrating the meticulous attention to detail in capturing real-world characteristics within the realm of computer graphics.

Figure 1: A pole displaying paint damage and amateur graffiti art.

Figure 2: An uneven-textured street, constructed with a variety of bricks and strewn with fallen leaves.

Figure 3: Wrinkle and Dirt mark on clothes.

Weathered Appearances

Weathered appearances play a pivotal role in diminishing the pristine quality of objects by simulating the natural aging process. As materials weather over time, they undergo changes such as cracks, scratches, and variations in color and texture. Incorporating these effects into virtual objects creates a sense of authenticity, breaking away from the initial perfection and introducing visual irregularities. The simulation of surface patina, rust, and other texture variations contributes to a more realistic and aged look. By capturing the impact of environmental conditions, such as sunlight exposure and moisture, weathered appearances enhance realism, making virtual objects appear as if they have been subject to genuine, real-world influences. In essence, the introduction of imperfections and the recreation of natural aging processes through weathered appearances collectively contribute to a convincing representation that moves beyond the pristine to embrace a more authentic and lived-in visual aesthetic.Different types of weathered appearances can be observed depending on the nature of the material, the environmental conditions, and the duration of exposure. The report will concentrate on Oxidation and Rust, dust accumulation over time, and Image degradation, delving into how these specific elements contribute to the overall weathered appearance of objects. Additionally, the focus will extend to understanding how these elements play a crucial role in enhancing realism, ultimately making the virtual objects more convincing and true-to-life.

Oxidation and Rust

Oxidation refers to the chemical reaction between a material and oxygen in the air, resulting in the formation of oxides on the surface of the object. Oxidation and Rust significantly enhances the authenticity of computer graphics, contributing natural effects to virtual elements and environments. The simulation of oxidation introduces genuine visual changes, such as alterations in color and texture, closely resembling real-world aging processes like the corrosion of metals. Accurate representation of how oxidized materials interact with light is also achieved, capturing shifts in reflectance and absorption. The simulation extends to the effects of oxidation on surfaces exposed to water and air, ensuring a realistic portrayal of environmental interactions. This approach allows virtual materials to respond convincingly to diverse lighting conditions and environmental factors. Through algorithmic modeling based on actual oxidation patterns, synthetic oxidation effects are generated.

The paper 'Rendering Imperfections' [1] discusses two methods for simulating oxidation and rust: employing physical models and utilizing image-based techniques.

- Physical Models: Virtual environments leverage physical models to simulate oxidation effects by replicating the chemical reactions and processes observed in real-world oxidation. These models are grounded in an understanding of the natural oxidation phenomenon and strive to mimic these processes within a virtual context. One strategy involves employing material-based simulations, where the material's properties, including its interaction with light and water, are defined. Accurately capturing these properties is crucial for faithfully representing the oxidation process. The model simulates how the material interacts with its surroundings, considering factors like exposure to moisture and air, to produce authentic oxidation effects.
- Image-based Models: These methods rely on data acquisition from real-world objects or scenes to create realistic oxidation effects. Multiple images are captured from different viewing angles, illumination variants, and stages of the weathering process. These images are then used to generate textures or maps that can be applied to virtual objects. Figure 4 exemplifies this approach, depicting a Buddha statue at different weathering stages, illustrating the method's efficacy in realistically simulating environmental influences on virtual objects.

Figure 4: A sense of time. On the left is a sequence of images showing the aging of a statuette. Time progresses from top to bottom. The larger image above illustrates the buildup of both the underlying smooth copper sulphide tarnish and the rough green patina (Dorsey and Hanrahan, 1996).

Dust Accumulation

Looking at Weathered Appearances, another important part is making virtual objects accumulate dust over time. This augmentation is achieved by introducing subtle visual cues and variations that closely replicate real-world settings. Dust, as it naturally accumulates on synthetic objects, adds a layer of authenticity to computer-generated images, mirroring the temporal changes observed in authentic environments. By simulating the gradual buildup of dust, the overall realism of computer-generated scenes is significantly heightened

Physically inspired approaches in computer graphics, such as the one discussed in the paper "Observation-driven Generation of Texture Maps Depicting Dust Accumulation Over Time" [2], aim to create realistic images without relying on complex and costly light simulations.Specifically, in showing how different levels of dust roughness affect surfaces and adjusting these effects based on changing light and viewing angles, these approaches significantly boost the realism in computer-generated scenes. The framework in the paper follows this method, using it to create textures that show how dust builds up on indoor surfaces, making computer scenes look more realistic as time passes. Figure 5 breaks down a layer of dust into two main parts: the opacity film and the granularity mask: This helps us understand that how a dusty surface looks depends on the level of dust roughness. We can imagine the dust layer as these two parts. The opacity film indicates how much the dust covers the surface, while the granularity mask reveals the locations and sizes of individual dust particles. Adjusting these components based on the viewing angle and light conditions contributes to creating realistic images of how dusty scenes evolve over time. The diagram emphasizes the transformation of the dust layer into the opacity film and the granularity mask, elucidating the relationship between the surface, the dust layer, and the final appearance of dustiness.

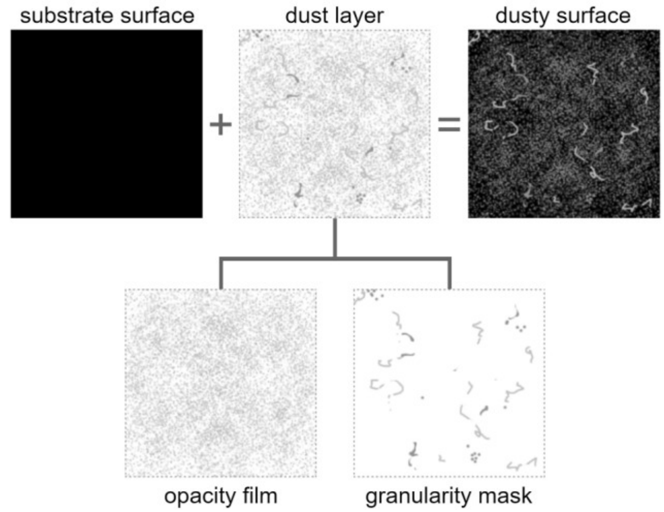

Figure 5: Diagram illustrating the contributions of fine and coarse dust components, respectively, represented by an opacity film and a granularity mask, to the appearance of dusty surfaces (Santos and Baranoski, 2022).

Image degradation

Continuing the exploration of the weathered approach, we delve further into techniques that intentionally introduce imperfections, artifacts, and degradation effects, contributing to a more authentic and lived-in appearance in computer-generated images. The primary objective is to make things look more real by imitating how they naturally age and wear out in the real world. This includes effects like scratches, stains, and fading, deliberately added to create a more authentic look in scenes. This is especially important when accuracy, aging, or historical aspects are crucial.

Moreover, image degradation extends its simulation to atmospheric conditions such as fog, haze, or dust particles, elevating the immersive and lifelike visual experience, especially in outdoor or environmental settings. By mimicking the imperfections found in reality, this technique strives to bridge the gap between pristine, computer-generated images and the nuanced realities of the physical world. Its significance goes beyond mere realism; image degradation provides a canvas for artists to express creativity, allowing intentional imperfections to contribute to the overall mood, narrative, or artistic vision of a virtual environment.

An intriguing aspect of image degradation involves introducing fatigue and wrinkle synthesis for clothing appearance, explored in computer graphics. This plays a pivotal role in enhancing realism by simulating the effects of time and wear on virtual clothing. Drawing inspiration from real-world garment design intricacies, this approach utilizes cloth simulation techniques to intentionally introduce wear and wrinkle effects, contributing to the authenticity and visual appeal of computer-generated scenes

The introduction of wrinkles involves a meticulous consideration of the hills and valleys of folds that naturally occur in fabric due to handling over time. By simulating curvature between neighboring triangles in the fabric mesh and recording folds, the simulation accumulates a "history" of wear, resulting in realistic discoloration and wear patterns. This detailed way of showing wear and tear makes virtual clothing look more real, fitting with the main goals of image degradation in computer graphics.

Figure 6 showcases the visual effects achieved through cloth simulation, specifically impacts, complex wrinkle patterns, fatigue, and specialty dye effects. The figure demonstrates how cloth simulation can mimic these real-world phenomena, thereby improving realism in computer graphics [4]. The impacts and wrinkle patterns generated through simulation contribute to the visual appearance of clothing, making it more realistic.

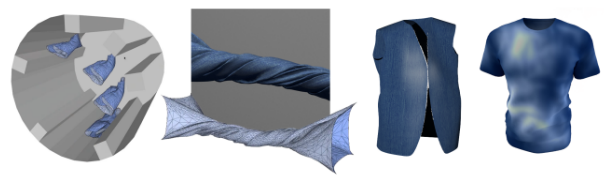

Figure 6: Cloth simulation produces impacts (left) and complex wrinkle patterns (left center) that can mimic fatigue (right center) and specialty dye effects (right) (Bermudez et al., 2019).

Advancements in Assignment 1 and Elevating Texture Mapping with Blender

Moving forward, our discussions will delve into the techniques utilized to elevate the realism of Assignment 1 and the models crafted in Blender. This exploration will involve diverse methodologies, such as bump mapping, displacement mapping, roughness mapping, and the application of diffuse and specular texture mapping

Bump Mapping

A bump map is a type of texture used in computer graphics to simulate surface bumps or irregularities on a 3D object without actually altering the geometry of the object itself. It works by manipulating how light interacts with the surface to create the illusion of depth and detail. Instead of physically changing the shape of the object, a bump map is a grayscale image where different shades of gray correspond to different elevations on the surface. Darker areas represent lower areas, while lighter areas represent higher areas. When light interacts with these varying shades, it creates the illusion of bumps, dents, or roughness on the object's surface .Figure 7 depicts a flat floor designed in Blender. When a bump map is applied to this floor, it introduces irregularities, making the surface appear less pristine. Upon examining both the wireframe and solid views, it becomes apparent that only four vertices are present. However, it's in the material view that we observe the ultimate transformation. Here, the illustration demonstrates how bump mapping has altered the simple image, resulting in a less pristine appearance.

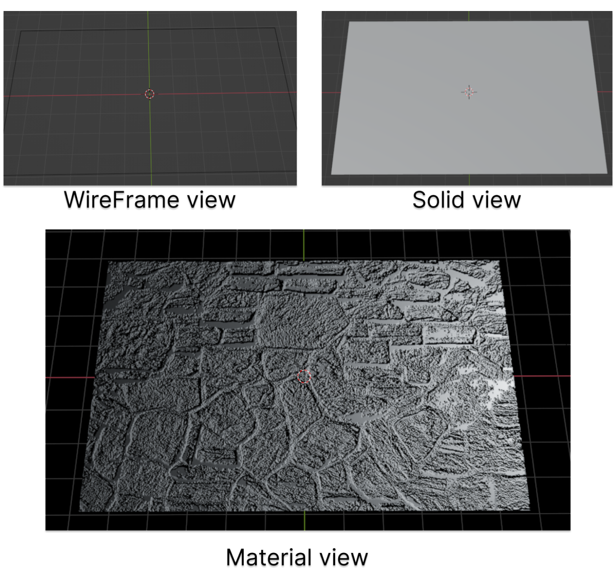

Fig 7 :A flat floor when bump mapping is applied (made using blender).

In Figure 8, we observe the application of bump mapping to the floor of Assignment 1. In the current implementation, a textured representation of the floor composed of bricks is incorporated. This texture is enhanced by blending it with a grayscale version of itself to effectively apply the bump mapping technique. As depicted in the output, the result showcases a floor that appears less pristine compared to the previous version. Using bump mapping doesn't just add depth; it also gives the floor a more realistic texture. It changes the floor from looking super clean to having a more natural feel. To further improve the technique of bump mapping, the paper titled "Real-Time, Accurate, Multi-Featured Rendering of Bump-Mapped Surfaces" [5] introduces an innovative rendering approach. This technique centers around normal map quantization, a process that significantly enhances objects with intricate geometric details. The approach involves quantizing the normals of the object's texture rather than its geometry, effectively merging quasi-coplanar regions into larger irregularly shaped flat parts.

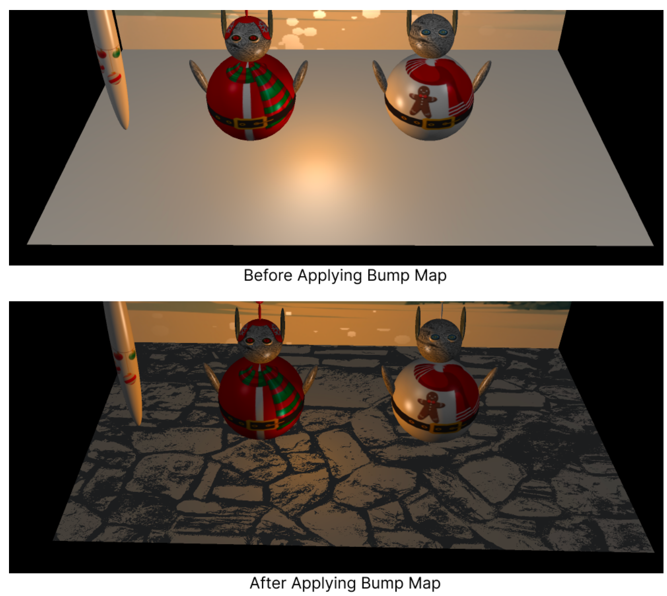

Fig 8 : Bumping applied to the floor of the room (changes made to Assignment 1).

By utilizing these quantized normals, the method achieves real-time rendering of objects, excelling in both rendering speed and quality compared to conventional methods. Moreover, this technique unlocks a range of visual effects, even for objects with substantial bump maps.

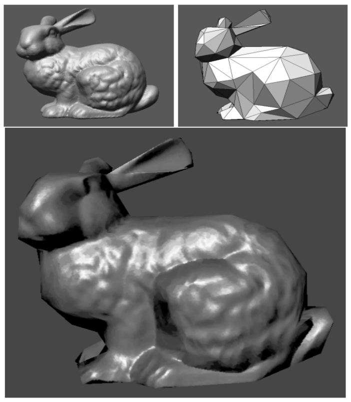

Fig 9: The Stanford bunny. Top-left: a rendering of the original model (69.4 K faces). Top-right: a highly simplified model (251 faces), where most of the high frequency shape detail is lost. Below: real-time bump-mapped rendering of the same simplified mesh, produced using a table of 2048 normals (Tarini et al., 2000).

Displacement Mapping

Displacement mapping is a computer graphics technique that enhances the detail and depth of 3D surfaces by physically altering an object's geometry. Unlike bump mapping, which simulates surface details without changing the geometry, displacement mapping deforms the object's vertices based on information from a texture or map. This texture dictates the height or depth of the surface, determining the displacement of each point along its normal direction. The direct impact on geometry is a significant advantage of displacement mapping, resulting in more pronounced and realistic surface details compared to bump mapping. This technique enhances realism by changing the object's shape, allowing for intricate features that cast shadows, interact with light sources, and contribute to convincing textures.

By introducing genuine changes to the geometry, displacement mapping contributes to making objects appear less pristine. It adds imperfections, roughness, and complexity to surfaces, mimicking the natural irregularities found in real-world objects. This technique is particularly effective in creating highly detailed surfaces, such as terrain, intricate patterns, or organic structures, enhancing the overall realism of rendered scenes by adding depth and tactile qualities to objects.

In Assignment 1, to make an alien face appear less pristine, it's crucial to avoid a perfectly uniform facial structure; a simple solid sphere won't achieve the desired realistic effect. Thus, incorporating displacement mapping as depicted in Figure 10 alters the object's geometry, evident in wireframe and solid views, resulting in a well-defined and realistic facial representation shown in the material view.

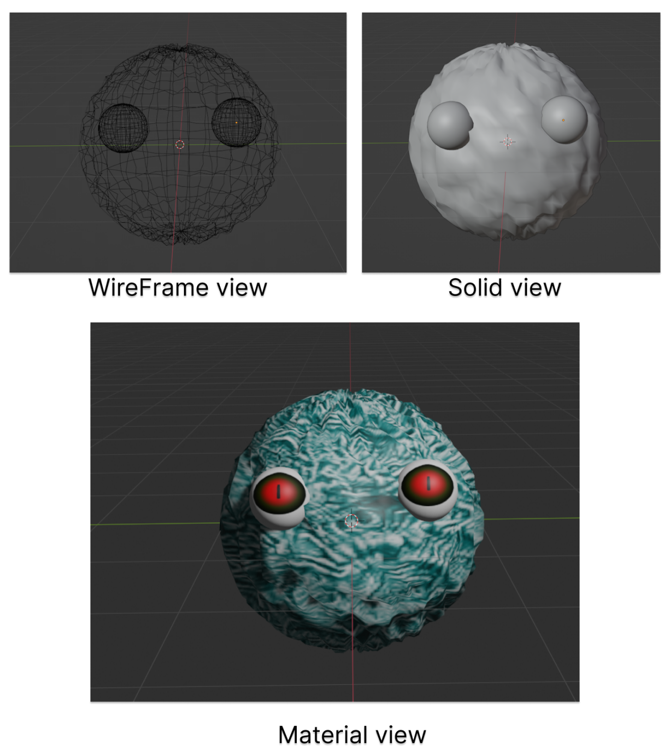

Figure 10 : Alien Head when displacement mapping is applied (made using blender).

Roughness Mapping

Roughness mapping in computer graphics simulates an object's microsurface details, specifically its roughness or smoothness. This technique, a component of physically-based rendering (PBR), enhances the realism of virtual objects by considering how their surfaces scatter light due to microscale variations. In this context, even seemingly smooth surfaces have imperfections, bumps, and irregularities affecting light interaction. Roughness mapping enables artists and developers to control and simulate these microsurface details, achieving a less pristine and more realistic appearance for virtual objects.

When combining the bump map, displacement map, and roughness map in Figure 15, we achieve a more realistic image. The figure illustrates a spotlight pole in Blender, resembling the one from Assignment 1, aiming to simulate the physical mode of oxidation. Oxidation effects are achieved in the image by combining the three discussed texture mapping techniques—bump mapping, displacement mapping, and roughness mapping—resulting in a more realistic appearance when illuminated.

For Assignment 1, the most straightforward and easy method to enhance the realism of the spotlight pole and alien cloth is to use diffuse and specular texture mapping. In case of the spotlight pole this approach was further augmented by incorporating bump mapping and making a few adjustments to the technique, particularly altering the oxidation effect based on the lighting conditions.

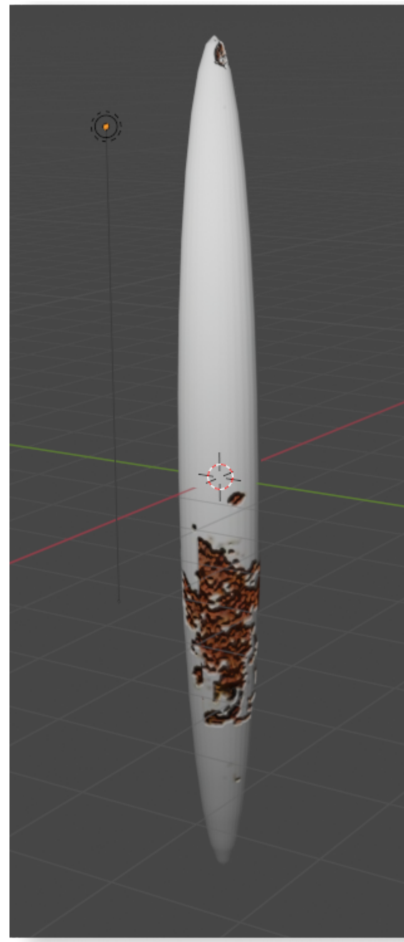

Fig:15. Spotlight Pole, when applied with all three mapping techniques—bump, displacement, and roughness—(made using Blender).

Figure 17 The weathered appearance of dust on the alien's clothing is applied as a diffuse texture on both the alien's clothes. This application contributes to improving the realism of the entire model by introducing a weathered and textured appearance to the alien's attire.

Figure 17: Alien Body after applying texture mapping (changes made to Assignment 1).

Figure 18: illustrates the transformation, comparing the left side of the pole before any modifications to the right side after implementing all the described mapping techniques. Notably, as the spotlight rotates, the oxidation or rust undergoes modifications based on light intensity. In lower intensity, the rust appears brownish, while in higher intensity, it takes on a darker hue.

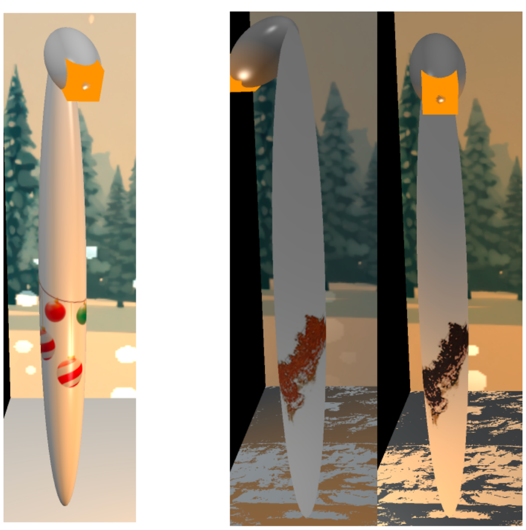

Figure 18: Spotlight pole, changed after applying texture mapping (changes made to Assignment 1).

Conclusion

In conclusion, the pursuit of enhancing realism in computer graphics centers on strategically introducing imperfections for a more authentic visual appeal. Figures 1, 2, and 3 highlight the importance of imperfections like accumulated dust, distinctive markings, and natural wear in shaping the authenticity of a scene. The integration of weathered appearances, including oxidation and rust, dust accumulation, and deliberate image degradation, significantly contributes to the lifelike portrayal of virtual objects.

Moving on to specific techniques applied in Assignment 1 and using Blender, we explored bump mapping, displacement mapping, and roughness mapping. Bump mapping, despite not altering the geometry, effectively adds depth and texture to surfaces, as shown in Figure 8. Displacement mapping physically alters the object's geometry, introducing imperfections, roughness, and complexity to surfaces, as illustrated in Figure 10. Finally, roughness mapping, a component of physically-based rendering, allows for the simulation of microsurface details, achieving a less pristine and more realistic appearance. Figure 15 combines these techniques, giving us a more realistic-looking spotlight pole with simulated rust. Further enhancements in Assignment 1 include the use of diffuse and specular texture mapping, refining the realism of spotlight poles and alien cloth.

In summary, by carefully applying these techniques, we can make objects and scenes look less pristine in computer graphics.

Reference

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