Irreversible Depth Cues in 2D Images: Algorithmic Innovations and Theoretical Explorations

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In the evolving field of digital imaging, the portrayal of depth within two-dimensional (2D) images presents both a fundamental challenge and a substantial opportunity for innovation. This paper explores novel approaches to embedding depth cues in 2D images that resist straightforward reverse engineering into three-dimensional (3D) data. Through a combination of experimental programming and theoretical modeling, we introduce three practical algorithms and propose five conceptual models, each designed to manipulate visual perception in uniquely irreversible ways. Our methods leverage advanced image processing techniques, including texture gradients, Perlin noise, and color-depth interplay, aiming to enhance visual security and enrich user interaction across various applications. By transcending traditional reversible techniques, these innovations offer new tools for artistic expression and practical application in fields ranging from entertainment to security, challenging and expanding the boundaries of visual representation.

Keywords: 2D image processing, depth perception, irreversible depth cues, texture gradients, Perlin noise, color-depth interplay, visual security, digital imaging, theoretical models, algorithmic innovation.

Introduction

The representation of three-dimensional (3D) space in two-dimensional (2D) images is a fundamental challenge in visual media. This process typically involves encoding depth cues—signals that provide information about the spatial relationships of objects in a scene. Conventional techniques for embedding these cues, such as perspective drawing, shading, and texturing, aim to offer a realistic depth perception. However, these methods often allow for the depth information to be extracted and reconstructed into 3D models. This reversibility, while advantageous for some applications, poses significant challenges in scenarios where the security and integrity of the visual information are paramount.

The Challenge

The primary challenge addressed in this study is the development of techniques to create depth cues in 2D images that are perceptible to human observers but resist straightforward conversion back into 3D data. This involves a sophisticated manipulation of visual cues that exploits the complexities of human visual perception without aligning strictly with geometric or physical accuracy. Achieving this requires an understanding of both the psychological aspects of depth perception and the technical aspects of image processing.

Importance and Applications

The implications of successfully addressing this challenge are wide-reaching:

1. **Computer Graphics and Visual Effects**: In the realm of entertainment, particularly in films and video games, there is a continuous demand for more effective and engaging visual effects. Techniques that create complex depth illusions enhance the viewer's immersive experience without the computational overhead associated with rendering full 3D scenes.

2. **Security**: In security applications, such as watermarking or steganography, embedding depth cues that cannot be easily reversed can protect against unauthorized copying or reconstruction. For example, a watermark that appears to have depth could be used to authenticate a document visually, but the lack of a straightforward method to extract it would prevent tampering.
3. **Augmented and Virtual Reality**: In AR and VR, optimizing the processing load while maintaining a high level of realism is crucial. Techniques that offer depth cues without true 3D data can reduce the computational requirements, allowing for smoother and more responsive experiences.
4. **Art and Design**: Artists and designers can benefit from methods that allow them to manipulate the perception of space in innovative ways. This can lead to new forms of expression and interaction in digital media, where the notion of space can be more fluid and dynamic.
5. **Scientific Visualization**: In fields that involve complex data visualization, such as medical imaging or astrophysics, being able to depict depth effectively on 2D displays can aid in the analysis and interpretation of multidimensional data.

This paper presents both implemented solutions and theoretical models that address these needs. Through a combination of algorithmic innovation and exploratory research, we aim to expand the toolkit available for manipulating depth cues in 2D images, thereby enhancing both the aesthetic qualities and functional applications of visual media across various disciplines.

Background and Related Work

Existing Methods for Generating Depth Cues

Depth perception in two-dimensional images is traditionally achieved through a variety of visual cues and techniques. These can be broadly categorized into several types:

1. **Linear Perspective**: The most common method, using converging lines and vanishing points to imply depth. This technique mimics the way parallel lines seem to converge at a distance in the real world.
2. **Shading and Lighting**: Techniques such as gradient shading, shadows, and highlights can suggest form and depth, simulating how light interacts with objects and environments. For example, shading under a ball can make a flat circle appear as a three-dimensional sphere.
3. **Texture Gradients**: The density or frequency of textures can vary with distance, providing cues about the depth of surfaces. Closer objects might have more detailed and distinct textures compared to those further away.
4. **Atmospheric Perspective**: Distant objects are often depicted with less contrast and a bluer hue due to the scattering of light by the atmosphere, a technique widely used in landscape painting.
5. **Stereoscopy**: By presenting two slightly different images to each eye, stereoscopic methods simulate the binocular vision of human eyes, creating a vivid sense of depth. This technique is prevalent in 3D movies and virtual reality.

These methods have been refined over centuries of art and decades of computer graphics research, forming the backbone of how depth is conveyed in 2D representations.

Limitations of Reversible Depth Perception Techniques

While effective for many applications, traditional depth cue techniques have inherent limitations, especially concerning reversibility and security:

1. **Reversibility**: Many traditional methods, especially those based on geometric principles like perspective, allow for relatively straightforward reverse engineering. Using algorithms, one can extract the depth data from images and reconstruct the 3D scene, which might be undesirable in sensitive applications.

2. **Lack of Robustness**: Techniques such as stereoscopy require precise control over viewing conditions and can be disrupted by minor changes in viewer position or device characteristics. This makes them less robust across different viewing environments.
3. **Computational Overhead**: Some methods, particularly those used in virtual and augmented reality, require significant computational resources to render realistic 3D scenes dynamically based on 2D data.
4. **Artistic Limitations**: Artists often need to balance realism with artistic intent, which can be constrained by the technical requirements of traditional depth cues. This can limit creative freedom and the ability to portray stylized or abstract imagery effectively.

Understanding these methods and their limitations sets the stage for the development of novel techniques aimed at creating irreversible depth cues. Such techniques would ideally prevent easy extraction of 3D data while still providing convincing depth perception, catering to needs in security, entertainment, and beyond. This paper builds upon the foundation laid by traditional methods, proposing innovative approaches that address their limitations and expand their possibilities.

Methodology

Approaches Taken

This study employs a dual approach combining practical algorithm development with theoretical modeling to explore innovative ways of embedding depth cues into 2D images. Each approach is designed to challenge the traditional reversibility of depth cues and aims to provide novel solutions applicable across various fields.

Experimental Programming: The first approach involves the development of three distinct algorithms, each designed to manipulate depth cues in unique ways. These algorithms utilize texture gradients, Perlin noise, and color-depth interplay to achieve effects that are perceptually effective yet difficult to reverse-engineer. The programming tasks were iteratively designed, implemented, and tested to evaluate their effectiveness in simulating depth within 2D images.

Theoretical Model Proposal: Alongside practical programming, this study proposes five theoretical models that could potentially offer new paradigms for embedding depth information. These models include techniques such as dynamic element insertion, neural network-based depth cue encryption, and multi-spectral layering. Each model is discussed conceptually to explore its feasibility and potential implementation challenges.

Software and Tools Used

The methodology employed in this research relies on a variety of software and tools known for their robustness and wide usage in scientific and creative domains:

1. **Python**: All programming was carried out using Python, a versatile programming language favored for its ease of use and powerful libraries. Python's extensive support for data manipulation, image processing, and machine learning makes it an ideal choice for developing and testing image processing algorithms.
2. **NumPy and SciPy**: These Python libraries were used extensively for their numerical computation capabilities, particularly for operations involving arrays, matrices, and higher-level mathematical functions. SciPy's specialized modules for signal and image processing were crucial for implementing filters and noise generation.
3. **Matplotlib**: This plotting library was used for generating and displaying images within the Python environment. Its capabilities allow for detailed manipulation of image properties and interactive exploration of results.
4. **Scikit-image**: Leveraging this open-source collection of algorithms for image processing helped in more advanced image manipulation

tasks, particularly when working with color transformations and advanced filtering techniques.

5. **Development Environment**: All code was written and tested within Win 11 which provide an interactive coding environment that facilitates experimentation and immediate feedback. This environment was instrumental in visualizing data flows and debugging algorithms.

The combination of practical programming and theoretical discussions, supported by a suite of powerful software tools, provides a comprehensive approach to exploring new dimensions of depth perception in 2D images. This methodology not only tests the limits of current technologies but also opens the door to future innovations that could transform visual media across various platforms and applications.

Implementation of Practical Algorithms

Depth1: Texture Gradients via Gaussian Filters

Description: The first algorithm, Depth1, utilizes Gaussian filters to create texture gradients in a 2D image. This technique is based on the principle that the human eye perceives variations in texture density as cues for depth, with finer textures appearing closer and coarser textures appearing further away.

Implementation Details:

- A base layer of random noise was generated using NumPy to serve as the initial texture.
- This noise was then processed with a Gaussian filter from the SciPy library, which blurs the image in a way that the intensity of the blur increases from top to bottom. This gradient of blurring creates an illusion of depth by simulating a texture gradient.

- The parameters for the Gaussian filter (such as the standard deviation of the blur) were adjusted to optimize the depth effect.

Results: The resulting image shows a clear gradient from finer to coarser textures, effectively simulating depth. This method proved to be simple yet effective in creating a visual illusion of depth without any actual 3D data.

Depth2: Perlin Noise for Simulated Terrain Depth

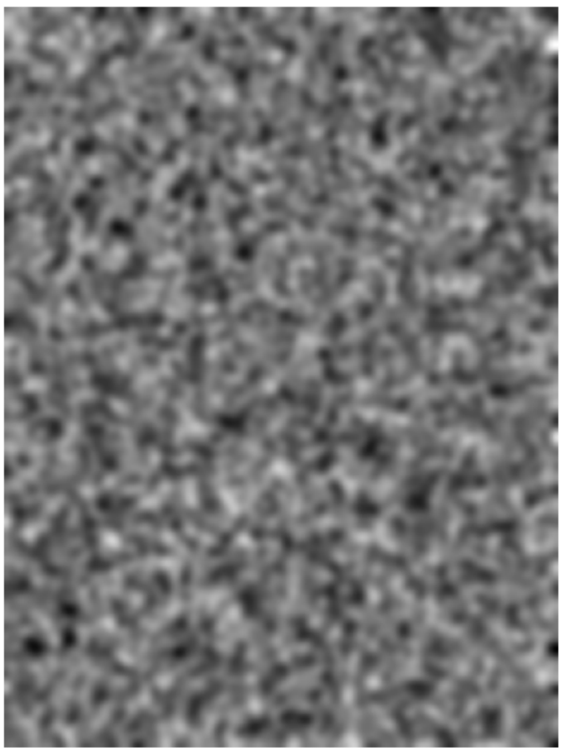
Description: Depth2 employs Perlin noise to simulate the appearance of a natural terrain landscape in 2D, where the varying noise patterns create a sense of undulation and depth typical of geographic terrains.

Implementation Details:

- Perlin noise was generated using a Python implementation available through the `noise` library, which provides a procedural basis for creating gradient noise useful in textures.

- The noise output was scaled and combined to form a complex pattern that mimics the randomness and subtlety of natural terrains.
- Additional image processing techniques, such as adjusting the contrast and brightness, were applied to enhance the depth perception conveyed by the noise patterns.

Results: The use of Perlin noise created an image with dynamic, terrain-like depth cues that appear three-dimensional to the viewer. This implementation highlighted the potential of noise functions in rendering realistic depth effects in purely 2D images.



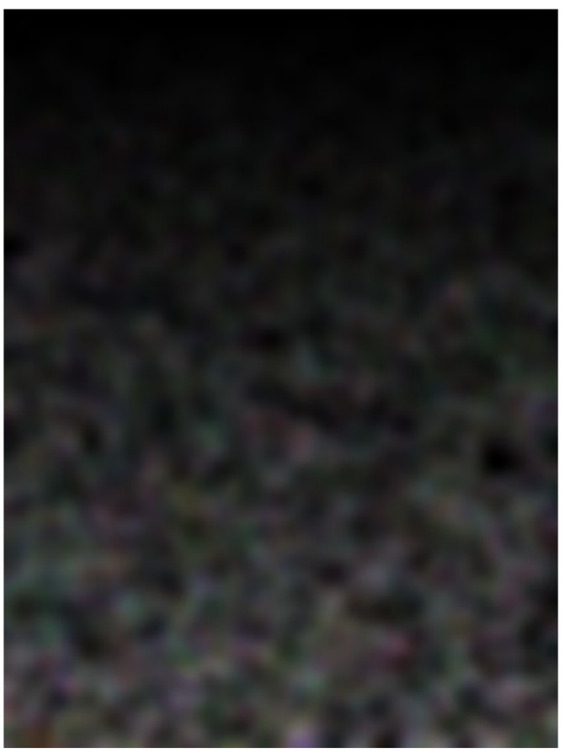
Depth3: Color and Depth Interplay using Gaussian Blurring and HSV Manipulation

Description: The third algorithm, Depth3, explores the interplay between color and depth by manipulating the color saturation and value gradients alongside spatial blurring.

Implementation Details:

- Initial random color fields were generated for the image using NumPy, creating a base layer with vibrant, varied hues.
- Gaussian blurring was applied selectively across the image to create a depth-based blur gradient.
- The color information of the blurred image was then converted from RGB to HSV color space using Matplotlib's color manipulation tools. The saturation (S) channel was selectively enhanced to amplify the depth effect by increasing color intensity at different depths.
- The final HSV image was converted back to RGB for display.

Results: This method successfully created a visually striking depth effect where color intensity and clarity varied with perceived depth, enhancing both the aesthetic appeal and the complexity of the depth cues.



Each algorithm demonstrated a unique approach to simulating depth in 2D images, leveraging different aspects of visual perception. The results confirm that depth cues can be effectively embedded in images in ways that are perceptually evident yet computationally obscure, thus offering new tools for artistic and practical applications in image processing.

Theoretical Models for Depth Perception

Dynamic Element Insertion

Conceptual Overview: This model proposes using elements in an image that dynamically adjust their appearance based on a simulated or calculated viewing angle. This dynamic adjustment aims to mimic real-world conditions where objects appear differently as the observer's perspective changes.

Potential Implementation Strategies:

- Develop an algorithm that alters visual elements in real-time based on input parameters that simulate viewer movement or angle changes.
- Use vector graphics to maintain image integrity during transformations and ensure smooth transitions between different appearances.
- Implement this concept in interactive media where user input can directly influence viewing angles, enhancing the immersion and realism of the experience.

Depth Cue Encryption via Neural Networks

Conceptual Overview: Utilizing neural networks, this model encrypts depth information within the visual properties of an image, making it difficult to decode without access to the specific model and its weights used for the encryption process.

Potential Implementation Strategies:

- Train a convolutional neural network to modify an image’s texture, lighting, and color based on depth data, then invert this relationship to obscure the depth information.
- Develop a proprietary training dataset that teaches the network how to embed and mask depth cues intricately.
- Ensure the network's output tweaks subtle visual cues that are perceivable but complex enough to defy straightforward algorithmic extraction of depth data.

Fractal-Based Depth Modulation

Conceptual Overview: This model explores the use of fractal patterns to create depth effects. Fractals are complex shapes that look similar at any scale and can be used to mimic the intricate details of natural objects, adding layers of depth through visual complexity.

Potential Implementation Strategies:

- Generate fractal patterns programmatically to overlay or integrate into images, adjusting parameters to vary perceived depth across the image.
- Experiment with different types of fractals, such as Mandelbrot or Julia sets, to study their impact on depth perception.
- Utilize fractal dimension as a parameter to control the level of detail and depth in different areas of the image.

Quantum Dot Color Dynamics

Conceptual Overview: Inspired by the properties of quantum dots whose color properties can change based on size and composition, this model suggests simulating these dynamics in digital images to create depth cues linked to color changes.

Potential Implementation Strategies:

- Simulate the light absorption and emission properties of quantum dots within a digital environment.
- Develop algorithms that adjust the color properties of pixels based on their depth information, mimicking the behavior of quantum dots under varying lighting conditions.
- Explore the use of this model in displays or printed media where color changes can be triggered by environmental factors.

Multi-spectral Layering

Conceptual Overview: This model involves creating images that contain multiple layers, each visible only under specific lighting conditions or through particular filters, similar to multi-spectral imaging used in scientific fields.

Potential Implementation Strategies:

- Design images with layers that respond to different wavelengths of light, possibly requiring specialized hardware to view all layers.
- Use digital filters to simulate the effect of viewing under different spectral conditions, allowing for depth cues to emerge as layers become visible or invisible.
- Apply this technique in augmented reality, where software can control the visibility of layers dynamically based on user interaction or environmental sensors.

These theoretical models propose advanced methods for embedding depth cues in 2D images, each leveraging different aspects of physics, perception, and technology. While these models currently exist at the conceptual level, their development could lead to groundbreaking advancements in how depth is portrayed and perceived in digital media, offering new possibilities for artistic expression, enhanced security, and interactive experiences.

Discussion

Analysis of Results from Practical Implementations

The practical algorithms developed in this study—Depth1 using texture gradients, Depth2 employing Perlin noise, and Depth3 integrating color and depth interplay—demonstrated the potential to effectively simulate depth in 2D images. The outcomes revealed several key insights:

- **Depth1**: The texture gradient approach was successful in creating an illusion of depth through the gradual variation in texture detail. This method proved effective in suggesting distance without requiring actual depth data, making it difficult to reverse-engineer.
- **Depth2**: Perlin noise generated a naturalistic appearance reminiscent of geographical terrains. This method illustrated how random noise could be structured in a way that mimics real-world topography, offering a visually rich depth cue that is complex to decode into specific 3D coordinates.
- **Depth3**: The combination of color manipulation and Gaussian blurring enhanced the depth effect through visual richness and subtlety. The HSV color space manipulation particularly highlighted how color intensity and saturation could be strategically used to augment depth perception.

These implementations, while effective, also faced limitations such as the dependency on specific parameters and the need for fine-tuning to achieve the desired depth effect, indicating a potential area for further refinement.

Potential Effectiveness and Challenges of Theoretical Models

The theoretical models proposed offer promising avenues for depth cue generation but come with their own sets of challenges:

- **Dynamic Element Insertion** and **Quantum Dot Color Dynamics** propose dynamic responses to viewing conditions, which while promising, would require complex real-time processing capabilities and possibly new types of display technology.

- **Depth Cue Encryption via Neural Networks** suggests a high level of security in embedding depth cues, but its effectiveness would heavily depend on the uniqueness of the training process and the neural network model, raising questions about accessibility and reproducibility.
- **Fractal-Based Depth Modulation** and **Multi-spectral Layering** introduce novel methods of embedding depth information. However, the computational complexity and the potential need for specialized viewing devices could limit their practical application.

These models highlight a trade-off between innovation in depth perception and the practicality of implementation, suggesting a need for continued research and development.

Comparative Analysis with Existing Methods

Compared to traditional depth cue methods such as linear perspective and stereoscopy, the techniques developed in this study offer unique benefits. They tend to obfuscate the direct path from 2D representation to 3D reconstruction, enhancing security and artistic freedom. However, they also require more sophisticated computational approaches and, in the case of theoretical models, further technological advancements.

Traditional methods remain effective for straightforward applications and environments where reversibility is not a concern. In contrast, the methods proposed here open new possibilities for applications requiring enhanced security or where computational resources are limited, as they could potentially reduce the processing needed compared to rendering full 3D environments.

This discussion underscores the innovative potential of the proposed methods while also recognizing the challenges and limitations they present. It emphasizes the importance of a balanced approach in choosing the right method for a given application, considering both the desired outcome and the practical constraints. As technology evolves, so too will the capabilities and applications of these depth perception techniques, continually expanding the boundaries of what can be achieved in digital imagery.

Future Work

Further Research and Development on Theoretical Models

The proposed theoretical models offer promising directions for deepening our understanding of depth perception in 2D images and expanding their applications. Future research could focus on several key areas:

1. **Prototyping and Testing Dynamic Element Insertion**: Develop initial prototypes that can adjust image elements based on viewing angle. Testing these prototypes in various interactive environments could provide valuable data on their effectiveness and user engagement.
2. **Exploring Depth Cue Encryption via Neural Networks**: Further research is needed to optimize neural network architectures for depth cue encryption. Experimental work could focus on the training processes, exploring different datasets, and neural network configurations to enhance the security and subtlety of the embedded depth cues.
3. **Advancing Fractal-Based Depth Modulation**: Investigate the use of different fractal patterns and their effects on perceived depth. Studies could examine the impact of fractal dimensionality on viewer perception and its potential applications in digital art and design.
4. **Developing Quantum Dot Color Dynamics Simulation**: Research into simulating quantum dot behaviors in digital environments could lead to new types of color-based depth cues. This work could involve collaboration with material scientists to accurately model the properties of quantum dots.

5. **Implementing Multi-spectral Layering**: This model could benefit from the development of software that simulates viewing conditions for different spectral layers. Such tools would allow for the practical testing and refinement of multi-spectral imaging techniques in digital media.

Improvements to Practical Algorithms

Based on testing and feedback, the practical algorithms developed in this study could be refined and improved in several ways:

1. **Optimizing Parameter Selection**: For all algorithms, automated methods for parameter tuning could be explored to enhance their adaptability and effectiveness across different images and conditions.
2. **Increasing Robustness of Depth1 (Texture Gradients)**: Research into adaptive filtering techniques could make Depth1 more effective across diverse image contents by dynamically adjusting the texture gradients based on the image's semantic content.
3. **Enhancing Realism in Depth2 (Perlin Noise)**: Integration of machine learning techniques to refine the terrain-like features generated by Perlin noise could improve the realism and applicability of Depth2 for gaming and virtual environments.
4. **Color Depth Interplay in Depth3**: Investigate advanced color theory applications to further refine the color-depth interplay in Depth3, possibly incorporating more sophisticated models of human color perception to enhance the depth effect.

The future work outlined above aims to address current limitations and unlock the full potential of the new methods for embedding depth cues in 2D images. By continuing to explore these areas, the field can advance towards more sophisticated, secure, and visually compelling digital imagery. This ongoing research will ideally foster a deeper understanding of visual perception while expanding the practical tools available for artists, designers, and technologists.

Conclusion

Summary of Findings

This study has demonstrated the feasibility and effectiveness of innovative techniques for embedding depth cues in 2D images that defy straightforward reverse-engineering into 3D data. Through the development of three practical algorithms—utilizing texture gradients, Perlin noise, and color-depth interplay—we have shown that it is possible to create compelling depth effects that enhance the perception of three-dimensionality without the actual three-dimensional information being readily extractable. Additionally, the exploration of five theoretical models has opened new avenues for research that promise to further enrich the toolkit for manipulating visual depth in digital media.

The results from the practical implementations confirm that subtle manipulations of texture, noise, and color can significantly affect the perceived depth in images, providing new methods for artists and designers to enhance visual storytelling and user engagement without increasing computational burdens typically associated with rendering 3D environments.

Implications for Image Processing and Visual Perception

The advancements discussed in this paper have significant implications for the field of image processing and the study of visual perception. They challenge traditional notions of how depth cues can be encoded and perceived in flat images, suggesting that our understanding of visual cues can be expanded and manipulated in innovative ways. This can lead to more sophisticated image processing techniques that are capable of producing more immersive and visually interesting content while potentially reducing the need for extensive 3D data processing.

Impact on Security, Entertainment, and Other Industries

In the realm of security, the ability to embed depth cues that cannot be easily reverse-engineered offers a novel approach to information protection. This could be particularly useful in areas such as watermarking, secure document printing, and anti-counterfeiting measures, where ensuring the integrity and authenticity of visual information is paramount.

In the entertainment industry, these techniques can be leveraged to create more engaging visual effects and virtual environments that are both resource-efficient and visually captivating. This could be especially beneficial in resource-constrained platforms like mobile gaming and augmented reality applications, where balancing visual quality with performance is crucial.

Furthermore, the exploration of irreversible depth cues has potential applications in educational and scientific visualization, where conveying complex data clearly and effectively is essential. The ability to manipulate depth cues could enhance the clarity and understanding of visual presentations, making them more accessible and easier to interpret.

Final Thoughts

The journey into creating irreversible depth cues in 2D images, as outlined in this paper, represents a promising frontier in digital imagery. As we continue to explore and refine these techniques, their potential to transform visual media and communication could be immense, impacting everything from art and entertainment to security and science. The continued exploration and development of these methods will undoubtedly lead to further discoveries that will enhance our ability to communicate and entertain through visual media, ensuring that the visuals of the future are not only more secure but also more intriguing and engaging than ever before.

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Depth 1

```
import numpy as np
import matplotlib.pyplot as plt

def generate_complex_depth_image(width, height):
    """
    Generate an image with complex depth cues using texture gradients.

    :param width: 400
    :param height: 300
    :return: None
    """
    # Create an empty image
    image = np.zeros((height, width))

    # Generate a horizontal gradient
    horizontal_gradient = np.linspace(0, 1, width)

    # Generate a vertical gradient that varies non-linearly
    vertical_gradient = np.linspace(0, 1, height) ** 2  # Squared for non-linear
variation

    # Combine gradients in a non-uniform way
    for i in range(height):
        for j in range(width):
            # Combine gradients with a sinusoidal modulation
            modulation = 0.5 * (1 + np.sin(2 * np.pi * (i / (height - 1)) * 10) * np.sin(2 *
np.pi * (j / (width - 1)) * 10))
            image[i, j] = horizontal_gradient[j] * vertical_gradient[i] * modulation

    # Display the image
    plt.imshow(image, cmap='gray')
    plt.axis('off')  # Turn off the axis
```

```
    plt.show()

# Dimensions of the image
width, height = 300, 400

# Generate the image
generate_complex_depth_image(width, height)
```

Depth2

```
import numpy as np
import matplotlib.pyplot as plt
from scipy.ndimage import gaussian_filter

def generate_simple_noise_image(width, height):
    """
    Generate an image with a simple noise pattern to simulate depth.

    :param width: Width of the image
    :param height: Height of the image
    :return: None
    """
    # Create random noise
    image = np.random.rand(height, width)

    # Apply a Gaussian filter to create smooth transitions
    image = gaussian_filter(image, sigma=3)

    # Normalize the image to [0, 1]
    image = (image - np.min(image)) / (np.max(image) - np.min(image))

    # Display the image
    plt.imshow(image, cmap='gray')
    plt.axis('off')
```

```
    plt.show()

# Dimensions of the image
width, height = 300, 400

# Generate the image
generate_simple_noise_image(width, height)
```

Depth3

```
import numpy as np
import matplotlib.pyplot as plt
import matplotlib.colors as mcolors
from scipy.ndimage import gaussian_filter

def generate_color_depth_image(width, height):
    """
    Generate a vivid color depth image using gradients, Gaussian noise, and
enhanced saturation.

    :param width: Width of the image
    :param height: Height of the image
    :return: None
    """
    # Base layer using random noise
    base_layer = np.random.rand(height, width)
    color_layer = np.random.rand(height, width, 3)  # For RGB colors

    # Apply Gaussian filters for smoothness
    depth_map = gaussian_filter(base_layer, sigma=5)
    color_map = np.zeros_like(color_layer)
    for i in range(3):  # Apply filter to each color channel
        color_map[:, :, i] = gaussian_filter(color_layer[:, :, i], sigma=5)

    # Normalize the depth map
```

```
    depth_map = (depth_map - np.min(depth_map)) / (np.max(depth_map) -
np.min(depth_map))

    # Create a depth effect using a vertical gradient
    vertical_gradient = np.tile(np.linspace(0, 1, height).reshape(height, 1), (1,
width))
    depth_map *= vertical_gradient  # Modulate depth by gradient

    # Convert RGB to HSV for better saturation control
    color_map_hsv = mcolors.rgb_to_hsv(color_map)
    color_map_hsv[:, :, 1] = np.clip(color_map_hsv[:, :, 1] * 2, 0, 1)  # Increase
saturation
    color_map = mcolors.hsv_to_rgb(color_map_hsv)

    # Combine color and depth
    final_image = color_map * depth_map[:, :, np.newaxis]

    # Display the image
    plt.imshow(final_image)
    plt.axis('off')
    plt.show()

# Dimensions of the image
width, height = 300, 400

# Generate the color depth image
generate_color_depth_image(width, height)
```