

Composition Principles for Quality Depiction and Aesthetics

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Abstract

Composition is an important aspect of both traditional illustration practices and non-photorealistic rendering methods. Composition means combining drawing elements such as line, tone, texture, focus of attention and arranging them in order, to make one cohesive unit. In this paper we present commonly used terms for drawing composition, present important key principles (unit, balance, center of interest, emphasis), and discuss how such principles are used to precisely convey the information to be depicted, with images embodying rich aesthetic qualities. We present two NPR experiments illustrating compositional principles and aesthetic implications in the context of line rendering of single 3D objects and global illumination mesh interior models.

Categories and Subject Descriptors (according to ACM CCS): I.3.2 [Computer Graphics]: Graphics Systems; I.3.3 [Computer Graphics]: Display algorithms; I.3.3 [Computer Graphics]: Line and curve generation; I.3.7 [Computer Graphics]: Color, shading, shadowing, and texture; I.3.7 [Computer Graphics]: Radiosity

1. Introduction

Illustration or drawing composition is a two-dimensional arrangement of drawing elements (i.e. line, shading, textures, focus of attention) on paper. It is the relationship among all the drawing elements, including the paper itself, which creates the composition. To this end, traditional illustrators and textbooks related to the craft set out rules, guidelines and principles concerning composition, established and adhered to for the sake of harmony, balance, and proportion. Indeed, such composition rules and principles can be applied to almost any subject matter and to many different drawings or paintings, ranging from the quickest of sketches to highly polished renderings of complex scenes.

Much of the research on non-photorealistic rendering (NPR) has focused on approximating specific natural media and related rendering techniques. However, to properly communicate visual information in a comprehensive and aesthetic way, artists must apply principles of composition properly integrating all drawing elements including line, tone, textures, focus of attention as exemplified by Figure 1. In this paper we present key principles of traditional drawing composition and demonstrate them in two NPR composition experiments. The first applies line-based rendering to single



Figure 1: *Focus of attention composition principle in traditional pen-and-ink drawing. Left: Focus of attention is above. Right: Focus of attention is below.*

three-dimensional objects. The second uses global illumination to render meshes depicting interior scenes.

The paper is organized as follows: The next section presents related work on artistic simulation and composition. Then in section 3 we describe composition principles and goals. In section 4 and 5 we present two case studies for

single objects and scenes. Section 4 presents an analysis of line type balancing in NPR drawings over implicit surfaces, as well as a discussion on the use of importance in this context. Section 5 presents an NPR multi-style approach which applies global illumination to achieve unity and balance. We also discuss the use of importance and contrast as a means to achieve emphasis and assign focus to relevant areas. Section 6 presents conclusions and future work.

2. State of the Art

Most of the work in NPR tries to simulate styles, materials and techniques from traditional drawing and illustration. One of the most important goals that is pursued is the automatic generation of lines, which are essential in shape recognition when reducing excessive visual information.

Line-based rendering systems rely heavily on the extraction of silhouettes and feature lines [IFH*03, FJW*05] from 3D objects. While the former are essential for conveying some of the most basic view-dependent features of a surface, the latter are used to depict surface discontinuities that are view-independent. More recently, a new class of lines, suggestive contours, was presented and formally defined by deCarlo et al. [DFRS03] as an effective means to convey surface features that are otherwise not covered by silhouettes and feature lines. The techniques adopted for identifying these elements are strongly tied to the representation used in each system, so it is natural to find a vast plethora of methods to extract them from polygonal meshes, implicit surfaces and volumetric data, among others.

As for line extraction, style simulation also plays an important role in NPR techniques. Indeed, impressionism, technical illustration, watercolor or pen-and-ink, are just some of the styles reproduced by researchers. However, in spite of the improvements devised to those techniques, they do not seem enough to reduce unnecessary information to rival the expressive techniques developed by artists over the centuries.

Winkenbach and Salesin [WS94] pioneered the principle of indication, which was thought to lend economy to computer-generated illustrations. In effect, by using some form of "indication", selected by the user, their system renders the final image without the need to use every stroke to represent texture. [GDS04] also explored this notion and used density measures to apply pictorial simplification styles where complexity is reduced either uniformly or in a spatially-varying manner through indication.

Other researchers manipulated light and shadows to apply composition principles. Strothotte et al. [SPR*94] rendered scenes to influence human perception. Effectively, their system allowed users to adjust rendering parameters such as shadow style, level of detail and center of attention, to create images according to a desired final composition. With a similar goal [KHRO01] manipulates objects to render a

scene based on user-defined composition rules. Gooch et al. [GRMS01] present an overview of basic principles and an algorithm to create simple images based on heuristic compositional rules. With a totally different approach, the principles of composition were also pursued by [AZM00] which combined different projections in the same image to create a variety of artistic effects. For instance, representing natural structures such as fur and vegetation was also a problem for researchers because of their complexity. Kowalski et al. [KMN*99] presented a method to suggest this complexity without explicitly representing it. Recently their work was extended to include a multi-resolution structure that allow continuous changing of detail according to view-dependent information [MMK*00].

Among the various composition techniques, emphasis was the most studied in recent years. DeCarlo [DS02] selected interesting regions in photographs using eye tracking data recorded from users. The result is a stylized and abstracted image, with detail preserved in the selected areas. More recent work [SD04] validated the system through user studies, showing that meaningful abstraction improves viewers' understanding of photographs. The selection of important information to help revealing relevant details was also used in [VKG04]. In this system, each object is rendered according to importance and viewpoint settings in order to maximize visual information. Recently [LME06] automated rendering parameter selection. In their system the selection is made using importance information, acquired with an eye tracker, and a set of heuristic rules.

3. Composition and NPR

Composition is an essential aspect in the creation of a vast variety of artistic work. It can be applied to almost any subject matter and is present in both traditional illustration and non-photorealistic rendering methods. The idea behind composition is the organization and arrangement of elements in order to create a unified work which communicates ideas and feelings to the viewer. That is, it is about giving purpose and meaning to a drawing, painting or any other kind of art work. To create a good composition, and thus, a good image - by good image we mean aesthetically attractive or emotionally appealing to the viewer - we have to manipulate the basic pictorial elements: line, shape, space, value, color and texture. To help on this there are a set of compositional principles which must be taken into account. They are unity, balance and emphasis, among others.

Each image is constructed around a subject. In general, its goal is to transmit an idea, information or feeling to the viewer. To express that particular thought, all the parts should be arranged in a homogeneous whole. This is what the principle of unity tells us: ordering the elements to create a unified aesthetic effect. However unity is not possible without balance. We need to balance the visual interest in an image to have a unified result. Balance establishes the equi-

librium of the visual importance and weight of each part of the composition, granting its correct share of attention. This doesn't mean, however, that attention should be equally distributed throughout the picture. Having the viewer's interest divided between several parts may reveal an unbalanced work. This leads us to other important composition principle: the emphasis and, in particular, the center of interest or point of focus.

To transmit an idea it is important to give emphasis to the right parts of an image. One way to attract viewers' attention is creating a focal point to be the first thing he or she looks at. This center of interest is revealed by the change of detail among the picture. Areas closer to the center have sharper details, while farther areas have less details. Another option to give emphasis to certain parts is by changing image's contrast. Areas with greater contrast will attract viewer's attention more than areas with less. Contrast could be used to give focus or just to reveal shape and particular object features. It also creates lines, or the illusion of lines, in a picture, which is a good way of leading the viewers to a certain point. Contrast is given by changes in color and value. The manipulation of value may also give or remove emphasis to objects or regions of a picture. Light and dark areas may suggest volume and reveal forms and shapes, and, at the same time, transmit feelings and sensations.

Each compositional principle is related to each other. To compose an image it is important to have in mind all the principles and merge the elements according to them. It is also important to reduce the unnecessary information which could distract the viewer from the subject. This may include extracting major geometric features using lines and contours, or manipulating light to leave in dark unimportant regions. In NPR these artistic principles may be achieved the same way as in traditional drawing and painting. In the next sections we will show two cases of the application of these principles. The first one presents techniques applied directly to objects, while the second presents techniques applied to the scene as a whole.

4. Object Level Techniques

In this section, we present line-based rendering techniques that illustrate some composition principles that were previously described. We use a practical application of the concept of importance for highlighting areas of interest through an increase in detail. The case study that is presented refers to the extraction of shape depicting lines directly from implicit surfaces.

The type of implicit surfaces that is used is the MPU (Multi-level Partition of Unity) [OBA*03], which is able to define complex objects from dense point clouds that can be obtained from scans of real objects. One important element that characterizes the MPU surface is an associated octree structure that covers its surrounding space through spatial

contiguous cells that are smaller and more numerous in areas of higher curvature. To identify areas of interest in the continuous structure of the implicit, a particle system is constructed to scatter points throughout the surface. From those positions, silhouettes and feature lines are extracted through iterative numerical integration processes and suggestive contours are obtained through particle identification, clustering and line-fitting methods. The MPU cells' dimensions are used as an heuristic for determining local curvature, which allows us to adapt the density of particles and the lines' precision according to the local shape. The next subsections will explore the aesthetical qualities of the extracted lines as well as the use of importance to adapt line complexity according to the user's interest.

4.1. Line Types

When we use a visual style such as line-based rendering, we must be very aware of the importance of the unity and balance principles of composition. Since we intend to depict shape only using curves, each type has a distinct purpose and reveals different characteristics of shape. Although curves are ideal to represent linear boundaries of surface features (such as explicit edges or silhouette boundaries), it becomes more difficult to appropriately convey features that span through a wider area (such as slight depressions or continuous variations of curvature). In the case study, three types of lines are used: silhouettes, feature-lines and suggestive contours. The correct extraction and stylization of lines ensures that we can surpass these difficulties, so we use line width, color and density to balance each type and form a unified whole that is both effective and aesthetically harmonious.

Silhouettes are probably the most fundamental curves in such a depiction and are frequently included in other distinct rendering styles. They are defined as the set of points in the surface whose normal yields a 90 degree angle to the incident view vector. They separate areas of the surface that are facing the view point and areas that are not and outline the 2D boundaries of the object's representation for any given viewing conditions. Therefore, they are view dependent lines that constitute the most basic visualization features of an object for any given scene. For this reason, they are the thickest and darkest lines that are presented in the drawing, in order to convey the steepness of the surface orientation regarding the viewer.

Feature lines are view independent, i.e. their existence does not depend on the viewing conditions of the scene, as long as the relevant surface areas are observable. They usually depict abrupt variations in curvature and can be extracted from 3D objects through various processes. In the presented system, they are identified as lines that separate surface faces which present an angle between their respective normals that is greater than a given threshold. This value is very important for the representation style as it controls

the feature-line density throughout the surface (Figure 2). In the case study, feature lines are drawn with the same dark color as the silhouettes but with less thickness, allowing the viewer to distinguish them in the overall drawing, in which silhouettes are more intensified. This is important to give higher emphasis to silhouettes in areas where both line types overlap, especially in surface concavities inside the 2D outline of the object. If the same style were to be used for both line types, the distinction might become impossible and the viewer would not capture the correct shape features.

Finally, the case study also presents a third class of lines: suggestive contours, which are view-dependent and provide visual information over some shape characteristics that may not be covered by silhouettes or feature lines. DeCarlo et al. [DFRS03] defines them as the set of points on the surface that, for a specific view point, belong to a silhouette that exists in a nearby view position but which does not have a correspondence to any of the silhouettes in the current one. Informally, suggestive contours appear in areas where the surface bends sharply away from the viewer but remains visible, i.e. they are almost contours. These lines help the viewer to better understand some of the surface features in areas where, although the curvature might not be very steep, an important variation of shape exists.

Regarding their relation to the other two types of lines, suggestive contours have a strong relation to silhouettes and many times compose extensions of these, denoting that a silhouette line will become longer in nearby view points. As to feature-lines, suggestive contours frequently overlap them in some viewing scenarios, because it is always probable that an area of high curvature will originate silhouettes for a series of view positions (and suggestive contours in nearby ones). However, the great importance of suggestive contours is to highlight certain shape features that will hardly be covered by feature lines (only when we use a low angle threshold for feature identification). One good example of this is the cheekbone of *David's Head* model presented in Figure 3. In terms of line stylization, suggestive contours are drawn with the same thickness as feature lines but with a slightly greyer tone, in order to transmit less aesthetical intensity. This is due to the fact that areas of high curvature, where suggestive contours may appear, are already depicted by feature lines and in other regions we want to express that there is an important shape feature to be noticed but the curvature is not as steep as in the other cases.

Figure 3 show us how the most important details of shape are transmitted by an appropriate composition with these three types of lines and the expressiveness power that can be obtained by balancing each type's contribution to the overall drawing.

4.2. Importance

As it was referred in Section 4.1, it is important to appropriately balance the line density produced for each line type



Figure 2: *David's Head* rendered through silhouettes and feature-lines, using different feature-line threshold angles: 0.25 rad, 0.20 rad, 0.15 rad.



Figure 3: *David's Head* rendered with three types of lines. Left: Only silhouettes. Center: Silhouettes and feature-lines. Right: Silhouettes, feature-lines and suggestive contours.

(especially feature lines) in line-based rendering, in order to, on one hand, convey the essential shape features of the surface and, on the other, avoid producing a line drawing that has an excessive number of elements. It is in this scenario that importance becomes a concept that can add value to the aesthetical side of the visual representation.

In the case study, an importance mechanism was developed to explore the possibilities of adapting the level of detail to the user's focal interest. An importance source is controlled by the user in a similar fashion as he could use a spot light to illuminate certain areas of the object. By defining in real-time the importance source's position, direction and amplitude, the user can define the area of focal interest where more detail is needed. This way, it becomes possible to render the overall surface using some basic lines and increase the number and type of lines that exist in the important region. Namely, non-focal areas can be rendered using only contours and a few feature lines (the ones that relate to areas of steep curvature, i.e. where a high threshold angle is met), while the focused parts are rendered using all of the three described line types.

This mechanism provides a flexible tool for adjusting the balance of line types to the user's needs. This becomes even more important in objects that have an extremely creased surface and therefore present lots of intricate details. One such object is the rock-like one in Figure 4, in which the feature line angle threshold has a dramatic influence in shape



Figure 4: Trapezium model. Left: Low detail rendering. Center: High detail rendering with a great density of lines. Right: The cone expresses orientation, position and amplitude of an importance source, which specifies an area of greater detail.

representation. If we use a high threshold, only the most profound shape features of the object are represented, which is adequate for transmitting a general notion of its topology. However, if we wish to have more shape information and detail, we must use a lower angle threshold that yields an overwhelming density of lines, which is confusing for the viewer. By using importance, it is possible to use the simplistic representation for a general view over the object (high angle threshold) and highlight all of the details in the focal interest area (low angle threshold), without damaging the overall harmony and aesthetics of the drawing. In data visualization applications, that many times deal with highly detailed 3D objects, this becomes a useful and powerful mechanism that allows the user to rapidly and effectively locate the surface areas of interest and visualize the local details, through an expressive and dynamic visual representation.

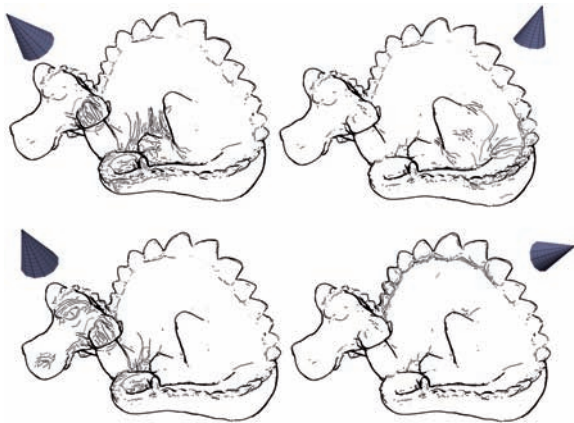


Figure 5: Rendering Phlegmatic Dragon model with importance. Top Left: Highlighting the leg area. Top Right: Highlighting the tail. Bottom Left: Highlighting the head. Bottom Right: Highlighting the back.

5. Scene Level Techniques

We present, in this section, a multi-style case study to explore the application of compositional principles directly to the scene. The methods used are applied directly to polygonal mesh scenes and based on a global illumination approach which supports the concept of importance, unity and balance. In the next subsections we will explain how we deal with these aesthetic issues and present some results.

5.1. Unity and Balance

Global illumination methods are used to create extremely realistic images. They are computationally expensive and thought to render each scene region in detail. The main goal of NPR is, however, to eliminate unimportant or excessive information. It is desired to keep only the details needed to transmit some idea or emotion. In account of these distinct goals, NPR researchers usually don't use global illumination in their systems, because they represent unnecessary computational effort. On the other hand, global illumination may be used to achieve unity and balance in a picture. As in reality, those methods distribute light in a continuous way, avoiding abrupt changes of value in the scene. By using a continuous distribution of light it is possible to create harmony and balance the image based on value. However, despite the usage of realistic illumination, it doesn't mean we are creating realistic images. We still transform light and compositional elements breaking nature rules, but we use its techniques to maintain the equilibrium. Global illumination helps preserving unity because it guarantees a connection between the elements, which avoids distracting the viewer from the whole.

In this system light and importance are pre-computed and passed to the GPU where NPR effects are generated. The viewer may control lighting exposure at any time, even after this pre-step. The viewer may also see the photorealistic result image, obtained after the light distribution.

5.2. Style Rendering

Artists choose style according to some goal or preference. The style used transmits a set of emotions and feelings, and changing it may transform completely the meaning and message transmitted. Choosing the style is an extremely subjective matter and depends entirely on the artist. In this system we use a multi-style approach. We simulate artistic styles by using pre-computed style textures. With this technique the viewer may change style while viewing the scene and, based on the immediate feedback, select the one that best achieves his or her propose.

Style textures are generated according to the method presented in [PHWF01]. That technique is thought to create pen-and-ink textures but can be expanded to create any kind of style that is based on drawing primitives' composition, such as points or strokes. For each style used, a set of TAMs are generated to be then applied, in real-time, to the image. This is done after the identification of each pixel color, in a pixel shader. The two textures closer to the pixel's color are selected and mixed to apply the correct value. By choosing two textures for each pixel, we avoid abrupt changes in the result. In Figure 6 we present two different styles for the same scene, a pencil drawing and a pen-and-ink drawing.

Besides choosing style, viewers may also apply some special effects to the actual scene. Since we just use monochromatic textures, we may combine colors with textures or invert colors. This process is also made in the pixel shader, after style textures' selection. Some of the effects that result from this technique are presented in Figure 7.

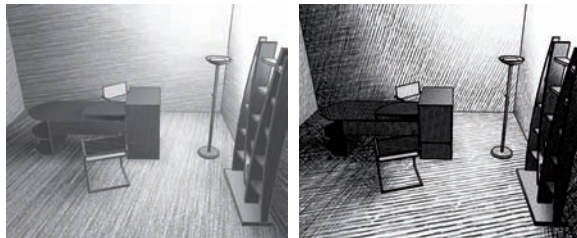


Figure 6: *The effect of applying different styles to the scene. Left: Pencil simulation. Right: Pen-and-ink simulation.*

5.3. Importance

The main issue of this framework is the use of importance. We use importance to identify the center of interest and emphasize relevant areas according to the focus. Importance is seen as a special light driving from the camera to the scene. This special light is distributed throughout the scene while normal lightening is estimated. This process could be done with any kind of illumination model. However, since we are using global illumination methods, importance has a continuous distribution as light itself. By using global illumination to distribute importance, we preserve image's bal-

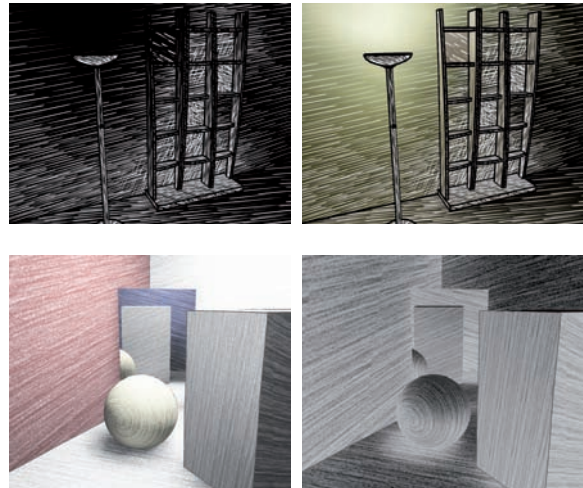


Figure 7: *Different effects achieved by mixing colors and style textures. Top left: Inversion of pen-and-ink style textures. Top right: Inversion plus mixing of colors. Bottom left: Mixing of colors with pencil style textures. Bottom right: Simple inversion of style textures.*

ance. It guarantees smooth changes of value and color since unimportant regions disappear according to their distance to important ones. Importance is balanced because we achieve equilibrium between important and unimportant areas.

After light and importance distribution, the scene is rendered. Light information is mixed with importance to identify per-pixel color which is then used to choose the style textures to apply. By default the importance source is the camera. If the viewer does not identify a different location, the viewpoint is used as source. Light and importance are mixed to enhance important objects and/or regions. This helps us giving emphasis to the right places of the scene. The viewer may activate or deactivate importance while walking throughout the scene or even change importance-contrast.

Importance-contrast is not the same as contrast. The second is related with light and color, while the first is related just with importance. When increasing importance-contrast the viewer is increasing the lap in detail between more important regions and less important, and when decreasing it the viewer is saying to decrease the differences between important and less important regions. In Figure 8 we may see the effect of activating and changing importance-contrast. In the first image the importance is deactivated, being difficult to identify the main focus. However in the other two images it is clear what is the center of interest, especially in the last one, which presents greater importance-contrast.

Another means to control emphasis is to change contrast. While altering contrast does not affect importance, it can change the saliency of areas in the image. By increasing

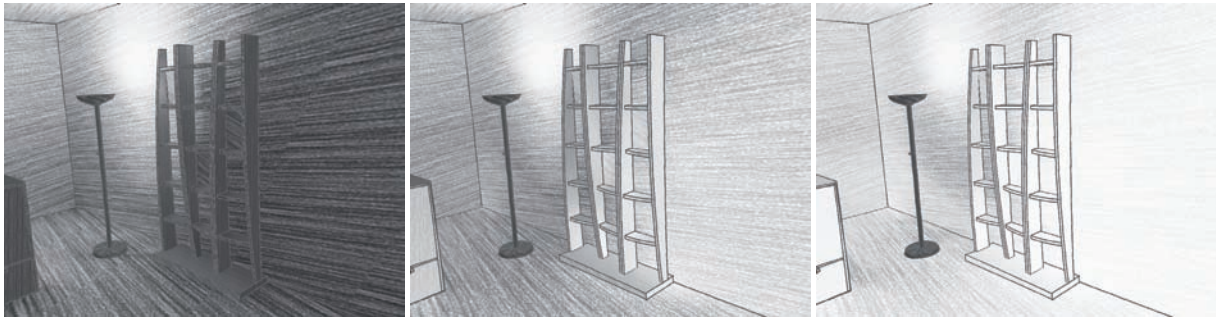


Figure 8: Use of importance to identify the center of interest. Left: Importance deactivated - it's difficult to identify the main focus. Middle: Importance activated - the lamp seems to be the center of interest. Right: Importance activated with greater importance-contrast - the lamp is even more emphasized.

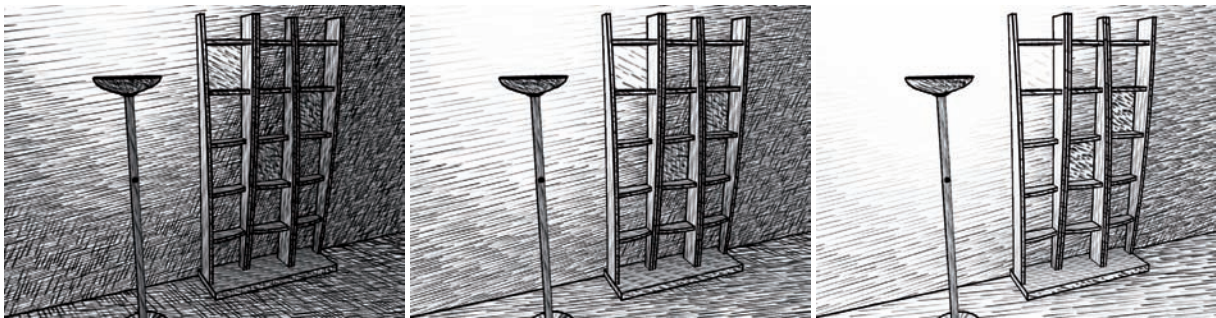


Figure 9: Changing contrast. Left: Less contrast than the middle image. Right: Greater contrast than the other two images.

the contrast we are turning light areas lighter and dark areas even darker. In spite of having no effect on importance, the use of contrast may help creating stronger boundaries which emphasize the forms of objects or regions. Tone differences due to increased contrast may also create the illusion of ghost lines which guide viewers' eyes. Figure 9 shows the impact of changing contrast. From the left to the right image, the contrast is being increased, clarifying forms and emphasizing borders. As we may observe in Figure 10, the method used to apply importance-contrast and contrast is similar, but the result is quite different. In the top images we may identify clearly a subject, especially when increasing importance-contrast, while the bottom images show greater form identification, no region is emphasized. Besides changing importance-contrast, the viewer may also invert importance, which means, important regions lose emphasis while unimportant areas become highlighted. This option is very useful because it completely changes the subject of the picture.

6. Conclusion and Future Work

Composition is an important issue in traditional drawing but little explored in NPR. Composition principles help artists to organize drawing elements and achieve an appealing and

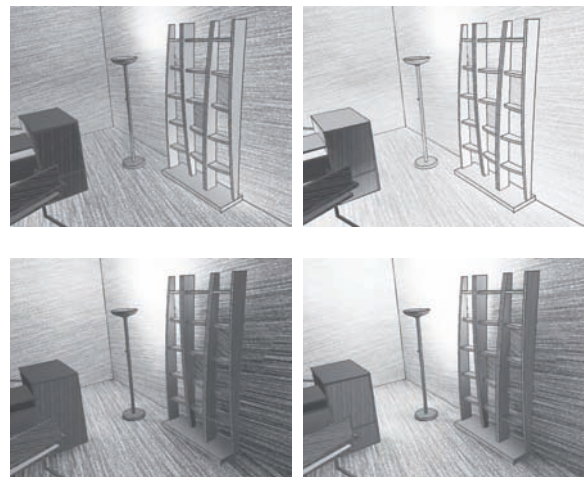


Figure 10: Importance-contrast versus contrast. Top: Increasing importance-contrast - desk emphasized. Bottom: Increasing contrast - all forms equally emphasized.

aesthetical result. Although line-based rendering and style simulation are essential techniques in NPR, when these are

applied guided by such principles, it is possible to generate images even more effective. In this paper we have presented two case studies that explore the main principles of composition: emphasis, unity and balance.

In the object-level case study, a line-based rendering system, we have shown that the composition principles of unity and balance are fundamental to effectively convey shape, as each class of lines serves a unique purpose and must be visually adapted to correctly “fit in” the overall drawing. We also explored the potential of using importance in 3D object visualization, to dynamically adapt line stylization and detail to highlight surface areas of interest as directed by users.

In the second case, rendering techniques directly applied to the scene are presented in a multi-style framework. We apply global illumination methods to ensure unity and balance, while importance and contrast serve to emphasize shape and create a focus of interest. Our system is also flexible in allowing the viewer to combine techniques and styles.

The cases presented both highlight and unearth new challenges in this area. Indeed, future work combining object level with scene level techniques would help to improve image quality and adapt the appearance of details. Indeed, understanding the importance of composition principles and the benefits of adjusting representation details to focus of interest are essential in NPR systems, to make rigorous visualization meet artistic expressiveness.

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