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Aesthetics of Hand-Drawn vs. Computer-Generated Stippling

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Abstract

Recent work in non-photorealistic rendering has produced results comparable to hand-drawn artistic images. Inspiration for such techniques has come from many traditional artistic techniques, such as pen-and-ink, to depict tone, depth, and shape. These techniques can create visually appealing images and increase understanding as is evident in their use in medical textbooks, popular science, etc. However, when computer-generated images are visually compared to similar hand-drawn images, studies have shown that subjects are generally able to determine differences between both images. This seems to indicate that there are different aesthetics associated with computer-generated images and hand-drawn images. This paper discusses the implications of varying aesthetics amongst hand-drawn and computer-generated images, focusing particularly on the application of stippling to provide tone and shape to an image.

1. Illustrating with Stippling

From hastily sketched figures on napkins to complex medical illustrations, hand-drawn images have long been used to convey information to people. Often, the information being presented will be condensed to the most important details by the artist, creating a simple, clear, and meaningful image. This refinement can be accomplished by directing attention to relevant features, simplifying complex features, or exposing previously obscured ones. This selective inclusion of detail provides illustrations with levels of expression not found in photographs. Many techniques found in illustrations have been adopted in an area of computer graphics known as non-photorealistic rendering (NPR). Particular focus has been given to pen-and-ink techniques which attempt to mimic artists' strokes, textures and tones through the placement of lines and points of varying thickness and density. To better highlight the differences amongst computer-generated images and hand-drawn images, we will focus solely on stippling as a subset of pen-and-ink.

In stippling, dots are deliberately placed on a surface of contrasting color to obtain subtle shifts in value. These dots can be varied in size, volume, and arrangement to create the illusion of different texture, tone, and shape, as shown in Figure 1. Stippling describes both an illustration technique and a visual style. When creating a stipple image, the artist begins by placing dots randomly on the page and then gradually fills in areas from each "seed" dot [Hod89] in order to visually describe forms and objects. This is a purely black-and-white technique, meaning that 100% black marks are made on a 100% white ground, or vice-versa. As such, no gray marks are made. However, because the size and density of marks can be varied, the perception of shades of gray can be readily accomplished. Varying tones are created by placing stipples closer together to form dark regions and further apart to form lighter regions [Nic95]. In this case, individual marks are not important; rather, it is the sum total of the marks which create gray tones. In addition, stippling is capable of capturing a very wide dynamic range of tones, from

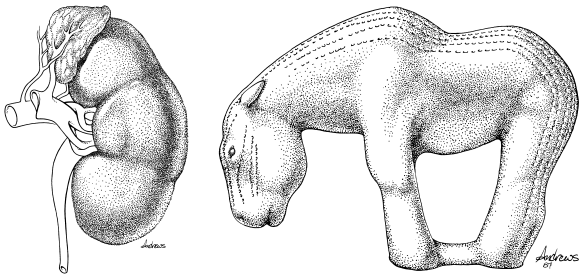


Figure 1: *Examples of hand-drawn illustrations that use stippling. Images copyright of William M. Andrews, used with permission.*

white to black. This range and subtlety allow very fine gradations between distinct tones.

Given the robustness of stippling, many computer illustration systems have developed stippling algorithms. Deussen et al. [DHvOS00] renders polygonal models into a continuous tone image and then converts these target images into a stipple representation. Their work suggests using a Poisson-disc distribution to simulate the artistic stipple distribution. In contrast to approximating stipples with a Poisson-disc, Secord [Sec02] uses a fast probabilistic method that places small arbitrarily-shaped primitives, including stippling. Lu et al. [LTH*02] introduced an interactive stipple rendering system. Here, the initial points for each polygon are generated randomly within the polygon and then redistributed to form a Poisson-disc distribution simulating traditional stipple placement techniques. Meruvia Pastor et al. [MPFS03] present an approach where stipple particles are attached to the surface of the model using a point hierarchy to control the stipple shading density, and Sousa et al. [CSFWS03] present a system which approximates stippling by using short serrated ink strokes that are modeled directly over the edge of the mesh. Schlechtweg et al. [SGS05] created a system that uses a multi-agent system called RenderBots to position NPR strokes, including stipples, based on a stack of G-buffers which are generated from a 3D model.

2. Two Different Aesthetics of Stippling

While these non-photorealistic stipple techniques are able to capture many aspects of the styles found in hand-made images, visible dissimilarities can be found between them. In a recent observational study comparing hand-drawn with computer-generated pen-and-ink drawings, Isenberg et al. found that participants were generally able to distinguish between both categories [INC*06]. For stipple images this was due to differences in stipple point density, the use of shading, and artifacts being present. These artifacts included unwanted regularities in the computer-guided dot placement, leading to the formation of lines as opposed to a more random placement of the dots in the hand-drawn images (Figure 2(a)). They also included intentional artifacts in the dot shape of hand-placed dots as opposed to the very regular and rounded computer-generated dots. These differences may not be purely observational, as an analysis of texture properties between hand-drawn and computer-generated images could potentially be used to classify them into separate categories of hand-drawn/computer-generated if the differences are common within a set.

However, Isenberg et al.'s study also showed that the differences between hand-drawn and computer-generated images did not necessarily lead to one category being more appreciated or liked than the other. In contrast, participants said that they like both categories of images for different reasons and would use them in different domains. This leads us to conclude that, while NPR techniques still hold potential for improvement, there may be two different types of aesthetics involved, one in hand-drawn and one in computer-generated stippling.

2.1. The Aesthetic of Hand-Drawn Stippling

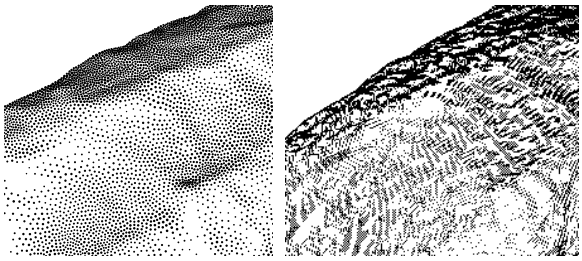
As a visual style, stippling fills an important role in medical, scientific, and technical illustration. With its ability to depict tonal variations, stippling is well-suited for illustrating objects with fine detail, subtle texture, and small changes in shading. A limitation of line illustration techniques in general is that the individual marks must be smaller than the finest detail that needs to be depicted. In stippling, this is rarely a concern. Gradients and soft edges are relatively easy to create by varying the size and density of marks. However, long lines and hard edges are relatively difficult to create using stipples. For particular illustrations, stippling is the preferred choice because other pen-and-ink techniques, such as hatching, may be mistaken for contours in the images. The random placement of stipples in medical illustrations provides for tone and shape, while not creating any undesired directional cues. This is not to say, however, that creating structures in stippling is always undesired.

In terms of stippling and the conceptual approaches an artist might take towards creating stippled illustrations, there are several inter-related issues that the artist must address. First, there are the physical characteristics of the marks, including mark size and variability, mark frequency and variability. Second, there is the issue of edge/shape handling: edge recognition and emphasis is crucial as it effects shape/form recognition and depth cues that arise from shapes interacting with one another. Finally, there is the issue of form/object shading which also serves as a means of emphasizing/de-emphasizing forms.

Furthermore, stippling is conceptually like half-tone printing, in which a continuous-tone image (photo or artwork) is converted to discrete dots in order to be printed using only black ink on white paper. The size and density of the dots determine the gray value of the tone printed. Where half-tone conversion typically uses a regularly arrayed screen for conversion, traditional stippling is accomplished through hand-eye coordination of the illustrator. There is enough variation in the placement of hand-made stipples to appear totally random. In a similar fashion, a stochastic (random or probabilistic but with some direction) screen can be applied to make the half-tone conversion, thus giving a more natural, stippled look to an image.

2.2. The Aesthetic of NPR Stippling

Creating stipples in non-photorealistic rendering is typically done by placing points explicitly or using small short strokes that approximate stippling. In Figure 2 we can see that both methods are fair approximations of stippling. Typical NPR stipple creation involves choosing a stipple primitive and a



(a) Explicit point placement using [Sec02]. (b) Short strokes generated by [CSFWS03].

Figure 2: *Points vs. strokes in computer-generated stippling.*

(a) Split finished granite. (b) Bluestone.

Figure 3: *Naturally occurring stipples. Images from [Jur96], copyright of Judy A. Juracek, used with permission.*

stipple distribution. Due to the nature of algorithmic stipple placement, computer-generated stipple illustrations can employ a much higher number and, thus, higher density of stipple points. This means that smaller dots can be used, resulting in potentially finer detail. Similarly, the strict use of both the model and a shading computation leads to an almost realistic depiction of the illustrated shapes. Another factor influencing the aesthetics of NPR stippling is the choice of dot or line shapes. Explicit point placement techniques usually employ dots ranging from perfectly symmetric to slightly irregular asymmetric but still rounded marks (Figure 2(a)) to simulate pure dot-by-dot stippling. The other type, short strokes, are typically asymmetric (Figure 2(b)) to replicate a stippling technique called *precise ink*. Depending on the type of rendering, the size of the marks is sometimes also close to the final resolution of a (pixel) image, leading to pixels or small groups of pixels representing one dot or one short stroke.

3. Distinguishing Between Hand-Drawn and Computer-Generated Stippling

While no formal metric has been introduced for distinguishing between hand-drawn and computer-generated stippling, it is clear that differences do exist. One such difference may be in the inherent preciseness of computer-generated stipples in comparison to hand-drawn stipples [INC*06]. This may lead subjects to sense a degree of sterility or rigidness in computer-generated stipples. However, such features may not always be undesirable. More detailed structures may show better shape, shading and illumination. Furthermore, computers are very good at creating patterns, which may be desirable in enhancing the perception of object features. Such structures may be more difficult to represent in hand-drawn images.

In contrast, hand-drawn images may feel less sterile as many natural surfaces (see Figure 3), have statistical properties that imply self-similarity. If these natural properties also exist in hand-drawn images, this difference could explain the visible dissimilarities between hand-drawn and computer-generated images.

However, if we are to consider this in terms of textures, it is possible that placing points explicitly, as opposed to placing small marks, will fall into separate texture classes: structural versus statistical [Har79]. Structural textures are defined as a set of primitive texels that contain some regular or repeated pattern, while statistical textures are defined in terms of a quantitative measure of the arrangement of intensities in a region. Currently, many mathematical procedures exist that characterize the spatial variations within textures as a means of extracting information. As such, it is possible that hand-drawn and computer-generated textures may have distinct characteristics that are inherently perceptible to the human visual system. Statistical methods could be used to analyze the spatial distribution of gray values by computing local features at each point in the image. These values could then be used to derive a set of statistics from the distributions of the local features [HSD73, WDR76]. Given the application of stippling to create varying gray values and the fact that the spatial distribution of gray values is one of the defining qualities of textures gives rise to the possible application of such techniques to quantitatively evaluate differences between hand-drawn and computer-generated images. Furthermore, if these textures do have underlying spatial structures, structural texture methods could be applied to define local spatial neighborhoods. The local spatial distributions in these neighborhoods could then be reflected in the shapes of the tessellations. Segmentation of textured images is one example of texture features based on Voronoi polygons [TJ90]. Gray level texture images have also been successfully segmented with identical second-order statistics through similar algorithms [OVOP01]. Despite their potential value, textural measures have not been exploited in any formal way for describing varying aesthetics in hand-drawn and computer-generated images.

4. Future Directions

This paper is intended as a position paper on the concerns of dissimilarities between computer-generated and hand-drawn pen-and-ink illustrations. We have discussed the different aesthetics of hand-drawn and computer-generated images

and commented on potential ways to analyze these differences. As such, we chose to focus on stippling to discuss these differences and address the possible implications on image aesthetics. Our overall concern is, given the inherent differences between hand-drawn and computer-generated stipples, what should our goals be in terms of modifying the aesthetics of NPR stippling? What should we retain, and what would benefit most from change?

From Isenberg et al.'s study we can see that subjects enjoyed computer-generated images for their accuracy/realness, while they also showed appreciation for the "character" of the hand-drawn images. This is similar to the difference between putting an image in a textbook or hanging it on your wall for pleasure. As such, one question is whether it is possible to create an image that seems highly accurate while still being such that a person would display it on their wall? Summarily, why do computer-generated images have a different aesthetic appreciation? Is this perceived feeling of accuracy or rigidity created inherently by the stipple placement algorithms, or is it just a cultural stigma that places computer-generated images in a separate category? Based on studies, it seems less likely that this is a stigma as previous studies have shown subjects to be able to easily classify most images into computer-generated and hand-drawn categories. If the images are so distinguishable, it would appear that this perception comes from the currently employed algorithms. We know that these algorithms differ by the types of marks and their distribution. As such, it would be interesting to analyze the potential different marks and distributions to determine which are perceived as more pleasurable. It is in this domain that texture analysis could potentially provide insight in classifying differences amongst hand-drawn and computer generated textures.

However, the overlying question is, does it matter that people can determine differences between computer-generated and hand-drawn stipples? In this paper, we have discussed the aesthetics of both hand-drawn and computer-generated stippling, outlining reasons why stippling is chosen in traditional illustration and the implications of this choice. We have compared the resulting image characteristics to the ones from computer-generated stippling, and we hope this will spark discussion on how to analyze and modify the aesthetics of computer-generated stipple images.

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