

# Colour Importance Driven Half-Toning

**Guerrero Roberto**

Dpto. de Informática  
Universidad Nacional de San Luis  
Ejército de los Andes 950  
San Luis, Argentina  
*rag@unsl.edu.ar*

**Buchanan John**

Electronic Arts Canada  
4330 Sanderson Avenue  
Burnaby, B.C., Canada  
*juancho@ea.com*

## Abstract

Importance driven half-toning (IDH) presents a method for reduced resource rendering of gray scale images. This approach uses an image pyramid to distribute drawing primitives to different areas of the image based on an importance function. The original paper showed how a wide variety of effects can be achieved using a combination of importance functions and drawing primitives. In this paper we show that by storing multiple pyramid representations of the image we can use different geometric primitives in different areas of the image.

The application of IDH to colour is then explored. We show that each of the red, green, and blue bands of the image can be used as bases for IDH. We show some images that are obtained in this manner. Finally we introduce a drawing mode based on a teaching drawing style (Esgrafiado with black ink) where a black layer is scratched off a coloured background. The resulting system provides the artist with a large number of parameters with which to render stylized images. We conclude the paper with some examples of our technique being applied to standard images.

**Keywords:** Half-toning, Bandpass pyramid, Importance function, Limited resource rendering, Non-photorealistic rendering, Multiple resolution representations, Multiple pyramids representation, Scratching off technique.

# 1 Introduction

It is now standard practice to present photos in a stylized manner. Common packages such as photoshop allows the user to alter the image in a variety of ways. There are a large number of filters that can be used to achieve a variety of effects. This interest in altering images has also driven a number of researchers to present techniques or filters with which the images can be altered [11, 1, 13, 6, 9, 8, 14, 15, 4, 12, 7, 5, 2, 3]. In this paper we present an extension to one such technique, Importance Driven Halftoning presented by Streit and Buchanan.

Importance Driven Halftoning [10] is a technique that allows the user to render an image using reduced resources. The idea behind this paper is straight forward. An image pyramid is constructed and then used to distribute a fixed number of drawing primitives.

Given a  $2^n \times 2^n$  image (the  $n^{\text{th}}$  level of the pyramid) the next level ( $n - 1$ ) is constructed by applying a  $2 \times 2$  box filter to the  $n^{\text{th}}$  level of the image (see Figure 2(a)). This process is repeated  $n - 2$  times until the image is represented by a single pixel whose value is the average intensity of the image.

Once the pyramid is constructed the drawing primitives are distributed in a recursive manner. The idea is to stand on top of the pyramid with a defined number of drawing primitives. At each point in the process we distribute the drawing primitives to the pixels on the next level down by looking at the intensities of the four pixels below. The relative intensities of the four pixels below are interpreted as the importance of each of these pixels (see Figure 2(b)). This process is repeated recursively for each pixel in the pyramid until we reach the bottom of the pyramid. When we are standing at the bottom of the pyramid we either have a primitive to draw with or we do not. In the case that we have a primitive to draw with we invoke the appropriate drawing routine.

Streit and Buchanan showed how this approach can be used to half-tone an image. They built the pyramid with the intensities of the image as the base level for the pyramid. The drawing primitives that they used were black pixels. The output image was thus initialized to white and pixels were set to black as described above. After showing how traditional half-toning could be achieved with this approach they then explored two further issues. Different rendering primitives, and different filters to construct the base level of the pyramid.



**Figure 1:** Lena, the ubiquitous image.

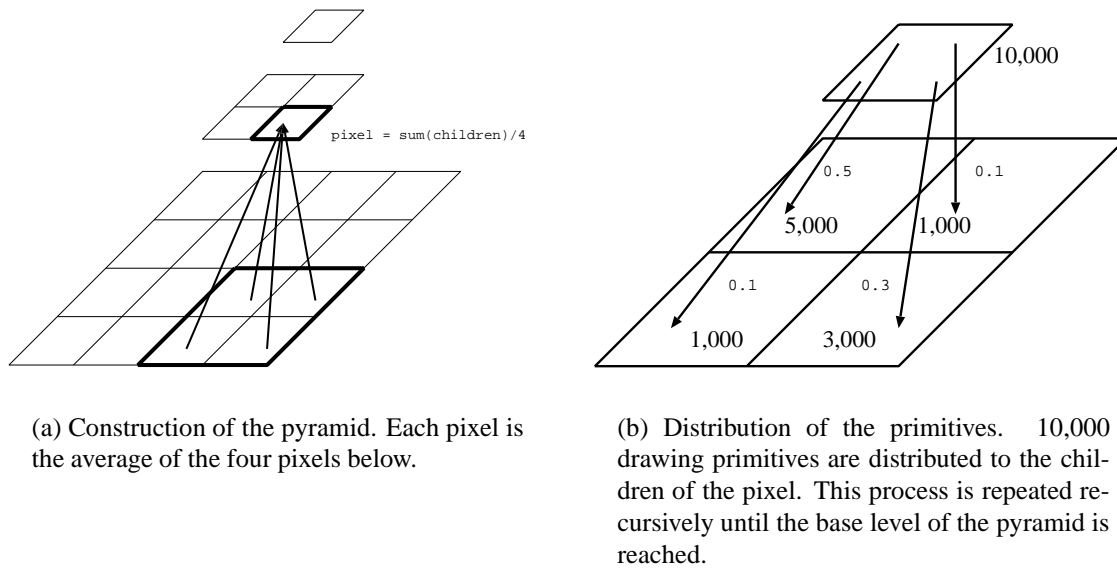


Figure 2: Importance Driven Halftoning Technique.

By using lines as drawing primitives they showed that stylized half-toned images can easily be achieved. They studied the use of lines with a constant length and orientation. This resulted in a hatched, sketchy look. They also showed that different image properties such as the gradient and variance can be used to alter the orientation and length of the line. This allowed a variety of styles to be studied. In particular if the line is scaled by the gradient strength and positioned at  $90^\circ$  to the gradient vector the edges of the image are accented.

Finally, Streit and Buchanan showed that different effects can be achieved by filtering the base level of the pyramid. In particular, if the base level is the gradient strength of the image then the importance pyramid represents how much gradient strength there is in each area of the image. When the primitives are distributed down the pyramid they will be distributed to areas of high gradient strength. This results in a half-toning of the image where the edges (high gradient strength) are drawn with more ink.

The base level of the image can be filtered with different linear combinations of filters. In particular a base image that is built of 75% intensity information and 25% gradient information results in a rendering of the image where the edges are strengthened (see figure 3).

Importance Driven Half-toning as presented by Streit and Buchanan uses a single pyramid to represent the image. This allows custom filters to be used to build the base pyramid but does not allow different drawing primitives to be used to accent different properties of the image. Streit and Buchanan did not explore the application of their technique to colour images. In this paper we address



Figure 3: 75% intensity and 25% gradient using Streit and Buchanan Method. Lines are of maximum length 20 and are set  $90^\circ$  to the gradient direction.

both of these issues. We first show that multiple pyramids significantly improve the IDH technique allowing a more tailored look to be developed for gray-scale images. We then present different ways in which this technique can be applied to colour images. In particular we introduce the idea of scratching off a coloured layer. This technique is then shown to be useful for the rendering of gray scale images.

## 2 Multi Pyramid Representation



(a) 75% of the drawing primitives are allocated to the intensity pyramid and 25% to the gradient pyramid. The intensity pyramid is rendered with points and the gradient pyramid is rendered using variable length lines that are at  $90^\circ$  to the gradient.



(b) 75% of the drawing primitives are allocated to the intensity pyramid and 25% to the gradient pyramid. The intensity pyramid is rendered with points and the gradient pyramid is rendered using variable length lines that are at  $90^\circ$  to the gradient, and are drawn in red.

Figure 4: Improved Streit-Buchanan results.

Streit and Buchanan showed how different combinations of importance functions can radically alter the look of the resulting image. Such an example image can be seen in Figure 3. This image clearly shows how the edges of a halftoned image can be enhanced. However it is not possible to further exaggerate the rendering of the edges of this image by using different rendering primitives for high gradient pixels. The drawing primitives are distributed based on the combined importance functions.

The algorithm for rendering an image using our approach then becomes

- Input from user, the number of pyramids and the filters associated with them, the number and type of rendering primitives used for each pyramid.
- Construct the  $n$  pyramids  $\Delta = \{\Delta_1, \Delta_2, \dots, \Delta_n\}$
- for each  $\Delta_i$  in  $\Delta$  do

- Distribute  $p_i$  primitives over  $\Delta_i$ , where  $p_i$  is the number of drawing primitives allocated to  $\Delta_i$ .
- Render  $\Delta_i$  primitives using the defined primitive (line, point) for this pyramid.

If the importance functions are used to build independent pyramids then we can make a choice at distribution time on how that importance function is going to affect the image. For example, following in the steps of Streit and Buchanan we want to highlight the gradient by using lines that are rotated  $90^\circ$  to the gradient but have constant length. This is done by distributing 75% of the drawing primitives (as points) on the intensity pyramid, and 25% on the gradient pyramid (as lines). The result of this operation can be seen in Figure 4(a). A slightly different rendering of this figure is seen in Figure 4(b), where red variable length lines (maximum length 20) are used to highlight areas of high gradient strength. This clearly illustrates that we can render different aspects of the image using different primitives.

### 3 Colour IDH

Extending a halftoning technique to colour is a straight forward task, namely halftone each image band (red, green, blue or cyan, magenta, yellow) independently. In this section we show that this is the case for IDH. The technique can be applied independently to each colour band and the images that are produced are what is expected. The parameter space of IDH is quite large as explained by Streit and Buchanan. To further enhance the richness of this parameter space we introduce the idea of scratching a layer off of an image. This simple idea translates into a wide variety of effects that can be applied to images. We finish this section off with a quick tour of this new enriched parameter space.

#### 3.1 Multi-Band IDH

When half-toning a coloured image it is common practice to half-tone each of the colour bands independently. In many cases a slightly different half-toning matrix [11] is used to ensure that the colour pixels are not always in the same position, this is important for many colour printers where the inks may not be completely translucent. It is natural then to attempt to use IDH on each of the colour bands of an image. We tried this on a number of images and found that the results were reasonable. The differences in the colour distributions translate into different importance pyramids for each of the colours. This means<sup>1</sup> that the distribution of the coloured pixels will be different for each of the colour-bands. This is illustrated in figure 5(a) where we half-tone the image using an intensity pyramid for each of the colour bands. A further example of this application of IDH can be seen in Figure 5(b) where we construct two pyramids (intensity and gradient) for each colour. The intensity pyramid was rendered using points and the gradient pyramid was rendered using lines. The resulting image illustrates that multi-band IDH produces images with a similar look to those produced by monochromatic IDH.

This approach provides us with the capability of halftoning images using IDH on each colour band independently. With careful tuning striking images can be produced. Based on our experimen-

---

<sup>1</sup>In the case that the red, green, and blue distributions are the same then the image is a simple gray-scale image.





(a) Independent rendering of red, green, and blue using the respective intensity pyramids



(b) 90% of the drawing primitives are allocated to the intensity pyramid 10% to the gradient pyramid. The intensity pyramid is rendered with points and the gradient pyramid is rendered with variable length lines set at  $90^\circ$  to the gradient direction.

Figure 5: Two different independent rendering.

tation all of the results and artifacts that were presented by Streit and Buchanan are reproducible in colour using this multi band approach.

## 4 Scratching off a layer

In South America a method of teaching painting exists, *Esgrafiado with black ink*. The basic idea is to cover a canvas with coloured paint that is then allowed to dry. The colour layer is then covered with a layer of black ink. The artist produces the image by selectively removing the black ink cover from the underlying coloured background.

Implementing this technique is straight forward. We allocate memory for two buffers, the background and the foreground. The over-layer is, in fact, the final image. The drawing routines are altered so that they set colours in the final image based on the colour of the under-layer. An example of this can be seen in Figure 7(a) where a image with a linear colour ramp is placed under a black cover. The strokes are defined by applying IDH to the image of lena. Each time a point or a line is drawn the colour of the primitive is defined by the background image.

In the traditional scratch black method there is little relationship between the background layer and the image that guides the strokes. Since the background layer is an arbitrary image we can use the same image for the background as we do for the stroke definition. In figure 7(b) we see how this combination results in a striking image.



(a) First step: painting the canvas.



(b) Second step: covering the canvas with black ink.



(c) Third step: drawing by removing the black ink cover.

Figure 6: The Esgrafiado Technique.

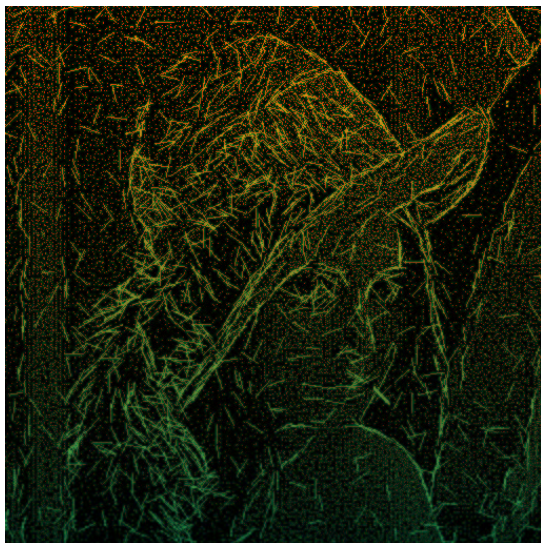
## 5 Example images

Colour IDH provides the user with a wide variety of options and parameters. Do we process the colour image colour by colour, or do we process the image based on some abstraction of the image. In many cases it is reasonable to build a grey-scale approximation of the image, whereas in other cases we want to process each colour independently. In our extensive evaluation of our system we have found that it is really easy to produce incredibly ugly images. There can be too many lines, the image can get lost in the effects, there may be a mismatch between the underlying image and the image being rendered, etc. This is a property that colour IDH shares with the work of Streit and Buchanan. But it is also the case that this property is shared amongst many other NPR systems or techniques. What this means is that the system needs to be used by an artist who understands the parameters and has a good idea of the desired effect.

In this section we present some of the more pleasant images that we produced during our exploration of colour IDH. For each of these images we discuss the parameters that were used and, if appropriate, the steps that we took to get to that image. We are going to use two foreground images to illustrate the technique. A photo of Lena (Fig. 1) and a painting by Calame (Fig. 8(a)). In our study of the technique we will use the painting by Calame and a painting by Ebert (Fig. 8(b)) as background images.

We found a nice rendering of Lena by combining all of the ideas in this paper. The image of Lena was covered with a layer of dark orange ( $r = 120, g = 60, b = 0$ ). We used two pyramids to render the image. The first pyramid is a grey-scale intensity pyramid and the rendering primitive is black points. The second pyramid is a gradient pyramid with lines as the rendering primitive. The lines are drawn using the colour of the underlying image. The result of this is seen in Figure 9(a). In order to illustrate how the first pyramid affects the texture of the image we present in Figure 9(b) the same image without the first pyramid. Comparing the two images it is very clear that there is a significant amount of texture added to the image in the first pass.





(a) The background image is a linear colour ramp. 95% of the drawing primitives are allocated to the intensity pyramid as points, 5% to the gradient pyramid as lines. Lines are of constant length 20 and are rotated  $90^\circ$  to the gradient.



(b) The background image is the image of lena. 95% of the drawing primitives are allocated to the intensity pyramid as points, 5% to the gradient pyramid as lines. Lines are of constant length 20 and are rotated  $90^\circ$  to the gradient.

Figure 7: Scratching off a black cover based on lena.

The painting by Calame presents an interesting challenge. The background in the sky has a significant number of artifacts from the canvas of the original painting. The lower part of the image is very dark with sharp contrasting renderings of the houses. The other aspect of this image is that there is a lot of gradient strength around the ridges of the mountains and around the houses in the village at the base of the mountains. This means that we had to be fairly selective in how we chose the primitives for the rendering of the image. We present two renderings of this image. The first (Fig. 10(a)) was rendered using a single pyramid based on the gray-scale intensity of the image. The rendering primitives are lines of variable length aligned at  $90^\circ$  to the gradient. The colour of the lines was defined by the original image. This image was constructed by scratching off a black layer.

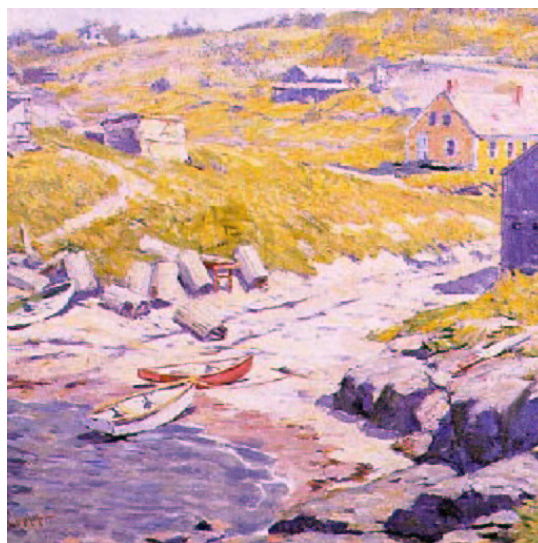
The second rendering of the Calame painting (Fig. 10(b)) was achieved by using two pyramids. The first pyramid is an intensity pyramid based on the gray-scale of the image, the second pyramid is based on the gradient of the gray-scale image. The rendering primitives associated with the first pyramid are points. The rendering primitives used to render the second pyramid are lines aligned at  $90^\circ$  to the gradient. The colour of the points and the lines are defined by the background image. The cover colour used was a gray image of intensity 45%.

Finally we show how two images can be combined using this method. The basic approach that works is to use two pyramids intensity and gradient. The intensity pyramid primitives (points) are drawn using the background intensity. The gradient pyramid primitives are drawn using black constant length lines aligned at  $90^\circ$  to the gradient. This brings out the elements of the front image. Two examples of this are presented in Figures 11(a) and 11(b). Comparing these two images illustrates that this automatic blending of images is not guaranteed to produce aesthetically pleasing images. We looked at a wide variety of images both as foreground and background prior to finding these two





(a) Painting by Alexandre Calame



(b) Painting by Charles Ebert

Figure 8: Two different background images

combinations. In many cases either the foreground image or the background image is not clearly visible. After our experimentation we know that images that have a simple set of edges work best as foreground images. The background image then has to be carefully chosen to blend well with the foreground gradient edges.

## 6 Conclusions

In this paper we have shown that IDH can be extended to colour images. We showed that the halftoning of colour images can be achieved by applying IDH on separate colour bands. This results in reasonable halftoning of coloured images. However, the major contribution is to show that the parameter space of IDH is significantly enriched by this extension to colour. In particular the idea of covering the image with a layered colour and then scratching has a lot of potential. We do not pretend to have completely covered or analyzed the parameter space of colour IDH. However, we believe that the images presented show the potential of this technique for rendering stylized images.

In addition to the extension to coloured images we showed that by separating the image pyramid into multiple pyramids the original IDH is improved. The improvement being that different rendering primitives can be used for different aspects of the image.

At last it could be interesting to show how this approach works with different kinds of drawing styles as those proposed by Hertzmann, Salesin and others.



(a) 95% of the drawing primitives are allocated to the intensity pyramid as black points, 5% to the gradient pyramid as lines with the background color. Lines are of constant length 20 and are rotated  $90^\circ$  to the gradient.



(b) 5% of the drawing primitives are allocated to the gradient pyramid as lines with the background color. Lines are of constant length 20 and are rotated  $90^\circ$  to the gradient.

Figure 9: Scratching off a dark orange cover based on Lena. The background image is the image of Lena.

## References

- [1] John Buchanan. Special effects with half-toning. *Proceedings of Eurographics 1996*, pages 97–108, 1996.
- [2] A. Hertzmann. Painterly rendering with curved brush strokes of multiple sizes. In *Proceedings of SIGGRAPH 98*, pages 453–460, 1998.
- [3] H. R. Kang. *Digital Color Half-toning*. SPIE Press, 1999.
- [4] P. Litwinowicz. Processing images and video for an impressionist effect. In *Proceedings of SIGGRAPH 97*, pages 407–414, 1997.
- [5] M. Salisbury M. Wong, J. Hughes and D. Salesin. Orientable textures for image-based pen-and-ink illustration. In *Proceedings of SIGGRAPH 97*, pages 401–406, 1997.
- [6] Victor Ostromoukhov, Roger D. Hersch, and Isaac Amidror. Rotated dispersion dither: a new technique for digital halftoning. *Proceedings of SIGGRAPH 94*, pages 123–130, July 1994. ISBN 0-89791-667-0. Held in Orlando, Florida.
- [7] M. Salisbury S. Anderson, R. Barzel and D.H. Salesin. Interactive pen-and-ink illustration. In *Proceedings of SIGGRAPH 94*, pages 101–108, 1994.
- [8] Mario Costa Sousa and John William Buchanan. Computer-generated graphite pencil rendering of 3d polygonal models. *Computer Graphics Forum*, 18(3):195–208, September 1999.

- [9] Mario Costa Sousa and John William Buchanan. Observational model of blenders and erasers in computer-generated pencil rendering. In *Graphics Interface*, pages 157–166, June 1999.
- [10] L. M. Streit and J. W. Buchanan. Importance driven halftoning. *Computer Graphics Forum*, 17(3):207–218, 1998. ISSN 1067-7055.
- [11] Robert Ulichney. *Digital Half-toning*. MIT Press, Cambridge, Massachusetts, 1987.
- [12] A. Girshick V. Interrante, S. Haker and T. Lemoine. Line direction matters: An argument for the use of principal directions in 3d line drawings. In *Proceedings of NPAR 2000*, pages 43–52, 2000.
- [13] Luiz Velho and Jonas de Miranda Gomes. Digital halftoning with space filling curves. *Computer Graphics (Proceedings of SIGGRAPH 91)*, 25(4):81–90, July 1991. ISBN 0-201-56291-X. Held in Las Vegas, Nevada.
- [14] G. Winkenbach and D. H. Salesin. Computer-generated pen-and-ink illustration. In *Proceedings of SIGGRAPH 94*, pages 91–100, 1994.
- [15] G. Winkenbach and D. H. Salesin. Rendering parametric surfaces in pen and ink. In *Proceedings of SIGGRAPH 96*, pages 469–476, 1996.





(a) The over-layer is a black cover. 100% of the drawing primitives are allocated to the intensity pyramid as lines with the background color. Lines are of variable length and are rotated  $90^\circ$  to the gradient.



(b) The over-layer is a gray cover (45% of intensity). The drawing primitives are distributed amongst one intensity pyramid and two gradient pyramids. 60% of the drawing primitives are allocated to the intensity pyramid as points with the background color, 25% are variable length lines rotated  $90^\circ$  to the gradient and drawn with the background color, 5% are lines of constant length 14, rotated  $90^\circ$  to the gradient and drawn in black color.

Figure 10: Scratching off a cover based on Calame painting. The background image is the Calame painting.



(a) Lena over the painting by Calame. The intensity pyramid is used to draw the background image through, and the gradient lines are drawn in black to highlight lena features.



(b) Lena over the painting by Ebert. The intensity pyramid is used to draw the background image through, and the gradient lines are drawn in black to highlight lena features.

Figure 11: Scratching off Lena image over different paintings.