Creating and Using Mattes for Video Compositing

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Abstract: Describes basic techniques for creating alpha channels in images and using them to combine different images and create unique effects. Includes techniques for reducing "blue spill" caused when using blue screens for extracting alpha channels.

When putting together digital imagery, it is often necessary to combine elements which were not filmed together, or which were generated on a computer. In this paper, I'd like to explore some of the techniques for putting together composited imagery.

Matte Channel Basics

The basic technique for combining images together is to create images which have a 4th channel (in addition to the red, green and blue color channels). The 4th channel, often called the "matte" or "alpha" channel, contains information about which pixels in the image should be included in the composite and which should not. For example, in figure 1a, we have an image of some characters filmed against a blue background. (Actually, I combined 2 separate images, hence the lighter background behind the leftmost character.) We want to composite this with the background in figure 1b to make it look as if the people were filmed in front of the background. We might have an alpha channel which looks like figure 1c for the foreground image, and an alpha channel like figure 1d for the background.

Figure 1a - Foreground

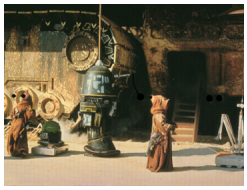

Figure 1b - Background

Figure 1c - Foreground Matte

Figure 1d - Background Matte

We see that in the foreground image's alpha channel, white pixels correspond to pixels we want to show up in the final image, and black pixels correspond to pixels we do not want to show up. The background image's alpha channel is the opposite of the foreground's in this case. Any pixels that are "off" in the foreground are "on" in the background image. The final composite would look like figure 2.

Figure 2 - Final composite

Image Operators

Images with a matte channel can be combined in a number of interesting ways using fairly simple math. To demonstrate, I'll use the following notation: "A" represents the pixels in the first image, and "B" represents the pixels of the second image. "a" represents the alpha channel of the first image, and "b" represents the alpha channel of the second image. When I write an equation like this:

Dest = A * (a) + B * (1-a)

it means that each pixel in the destination image is calculated by multiplying each pixel in image A by the value in its alpha channel at that pixel, and adding it to the corresponding pixel in image B multiplied by 1 minus the value of A's alpha channel at that pixel. The alpha channel is a grayscale channel, and its values are usually scaled to be between 0 and 1.

The above operation is called the "Over" operator, and would give us the result seen in

figure 2.

There are several more operators we can use for combining multiple images. These are the most useful ones:

Name	Formula	Description
A	Dest = A	Shows A
B	Dest = B	Shows B
A over B	Dest = A*(a)+B*(1-a)	Shows A and parts of B not covered by A
B over A	Dest = A*(1-b)+B*(b)	Shows B and parts of A not covered by B
A in B	Dest = A*(b)	Shows parts of A that intersect with B
B in A	Dest = B*(a)	Shows parts of B that intersect with A
A held out by B	Dest = A*(1-b)	Shows parts of A that don't intersect with B
B held out by A	Dest = B*(1-a)	Shows parts of B that don't intersect with A
A atop B	Dest = A*(b) + B*(1-a)	Shows all of B and those parts of A that overlap B
B atop A	Dest = A*(1-b)+B*(a)	Shows all of A and those parts of B that overlap A
A xor B	Dest = A*(1-b)+B*(1-a)	Shows parts of A and B that do not intersect

[Foley90]

Here are some examples:

Image A

Figure 3a - Image A

Image B

Figure 3b - Image B

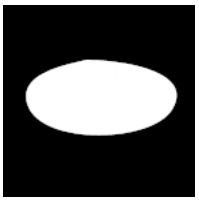

Figure 3c - A's matte

Figure 3d - B's matte

Figure 3e - A over B

Figure 3f - B in A

Figure 3g - A held out by B

Figure 3h - A atop B

Figure 3i - A xor B

Creating the Matte Channel

So now you know how to combine different images together to create interesting results. But how do you create the matte channel in the first place? There are a number of techniques, some of which you are probably already familiar with.

Luminance or Luma Key

One simple way to create a matte from an image is based on the "brightness" of the image at each point.[Brinkman99] Brighter values become white in the matte, and darker values become black. I put the term brightness in quotes because brightness is a perceptual quality. Objects in an image will appear brighter or darker, depending on the color of surrounding objects. Moving the same object

into another image will make the brightness of that object appear different than in the original image, despite the fact that the actual pixel values are the same, and that the monitor is outputting the same amount of light at those points. [Brinkman99]

To further confuse the issue, the terms luma and luminance are often used interchangeably, and / or incorrectly.[Poynton99] Without going into further detail, suffice it to say that we'll use these equations to represent luminance and luma:

luminance = 0.2125 * r + 0.7154 * g + 0.0721 * b

and

luma = 0.299 * r + 0.587 * g + 0.114 * b

where r, g and b represent the red, green and blue channels of an image, respectively. (For a much more in-depth discussion of brightness, luma and luminance, see Charles Poynton's ColorFAQ, referenced in the bibliography). Which you choose to use is up to you, and will probably depend on which gives a result closer to what you want.

Calculating the luminance or luma at each point can give us an alpha value for each point in the image. This technique works best when the background is very dark and the foreground object you want to extract is very bright.

Chroma Key

Another obvious way to create a matte channel is to use the traditional "weather reporter" approach. Film your subject in front of a solidly colored background. Then every pixel that's close to that color becomes black in the alpha channel, and every pixel that's not becomes white.[Brinkman99] In news broadcasts, this is often achieved by having the weather reporter stand in front of an evenly lit blue screen. All the blue pixels then become black in the alpha channel, and are replaced with an image of a weather map. Straight application of this technique can leave a halo around the subject, so there is usually a control which allows you to include colors which are close to the chosen hue. In addition, some tools will allow you to specify more than one color to use for the key, or to sample different parts of the image with an "eye-dropper" tool to get as close as possible to the desired color.

To create a matte from an image using a chroma key, simply allow the user to choose a color in a hue and saturation based color space (or convert a color they choose to a hue and saturation based color space), and make every pixel in the alpha channel black, if it corresponds to that hue. You may want to limit the saturation and brightness of the chosen color to be within a certain range, as well.

Difference Matte

If the background of the scene you're working with is static, you can extract a matte fairly easily. Simply take a picture of the background before filming the scene, then subtract that picture from each frame of the sequence.[Brinkman99] The background will become black, and the foreground will be any areas which are not black. You will probably have to clean up the resulting sequence, due to natural shifts in lighting, shadows, and variations caused by the equipment. There are some techniques for doing so listed at the end of this section. Adding a threshold, as shown below, is one simple way to improve your results.

```
tempRed = A.red - staticImage.red
tempGreen = A.green - staticImage.green
tempBlue = A.blue - staticImage.blue
tempAvg = (tempRed + tempGreen +
tempBlue) / 3;
if (tempAvg < threshold) {
        A.a = 0;
} else {
        A.a = 1;
}
```

Color Difference

The technique used in most Hollywood movies

is a technique known as color differencing. It was first used in the 1959 production of Ben Hur. Color differencing involves modifying the image in addition to producing the matte channel.

Let's take the example of a subject filmed against a blue screen, as we did with the chroma key. We want the blue areas to become transparent in the final composite. We could use a chroma key, but the edges will often not look right, and areas of wispy blonde hair will have an annoying halo around them. To account for this, in our first step, we modify the image so that if the blue channel is greater than the green channel, we replace it with the green channel. Like this:

```
if (src.blue > src.green) {
        dst.blue = src.green;
} else {
        dst.blue = src.blue;
}
```

This is known as spill suppression. When lighting a scene and using a blue screen, some light reflecting off the blue screen will "spill" onto the subject and slightly change its color. The above operation reduces the effects of the "spill". At this point, our image becomes black wherever the blue screen was, and the rest of the image (hopefully the content we want to be opaque) is slightly modified so that the blue channel is never greater than the green channel. This can have the effect of giving an unwanted color shift, which may need to be addressed later in the process. However, when filming in front of a blue screen, you usually avoid elements which have a lot of blue in them to minimize these types of color shifts.

Next, we create the matte channel by subtracting the maximum of the red and green channels from the original blue channel, like this:

```
dst.alpha = src.blue - max(src.red, src.green);
```

This is where the name of the technique, "Color Difference", comes from. This will actually produce an inverted matte, so we must invert it back to normal like this:

```
dst.alpha = 1 - dst.alpha;
```

[Brinkman99]
At this point, you'll probably need to adjust the resulting matte. Adobe Premiere uses a histogram adjustment to get the matte just right. It works much like the "Levels" dialog of Photoshop.

Here is what the various stages look like:

Figure 4a - Original image with blue background

Figure 4b - Image with spill suppression applied

Figure 4c - Final image matte after difference and inversion (and histogram adjustment)

Figure 4d - Final image combined with background

Computer Generated
If you are working with synthetic images, you

can probably get the application which generated them to output alpha channels for all of your images. This has the advantage of always having the proper coverage of the foreground objects. If the software you are using does not output alpha channels, most of the techniques described above will work, too. The advantage of using them on computer generated imagery is that there are no variations in the lighting and no dust or scratches on the film to cause problems.

Hand Made
If you are not working with computer generated imagery, you still have the option of creating the matte by hand. Most popular image editing applications will allow you to add an alpha channel, and allow you to paint on it, and even apply filters. This is usually too time consuming of a task to perform completely by hand for every frame of a sequence, but it can be useful for touch-up work, or when working with a static object.

Garbage Mattes and other techniques for cleaning up mattes
You'll find that when when generating mattes using algorithms, there will always be areas which don't quite look right. For example, using a luminance key for the image in figure 5a below, generates the matte in figure 5b.

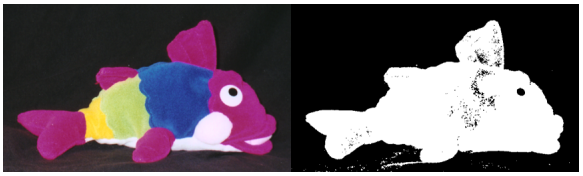

Figure 5a - Original Figure 5b - Luminance Map

Notice that the black part of the eye becomes transparent where we don't want it to be, and there are some dark areas which are also incorrect. We can apply a "garbage matte", like that in figure 5c to cover the area of the object we want changed. A garbage matte is simply a hand generated matte that we apply over our computer generated matte for filling in areas which are inside the computer generated matte, but were generated incorrectly.[Brinkman99] The result of combining the 2 is in figure 5d

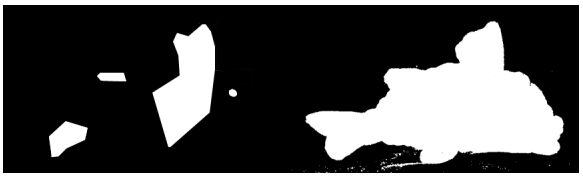

Figure 5c - Garbage Matte Figure 5d - Garbage Matte applied to original

Another possibility in some cases is to simply apply a contrast adjustment to the computer generated matte. This will cause nearly transparent areas to become transparent, and nearly opaque areas to become opaque.

Using Mattes for Special Effects
The "Over" operator allows us to do the most useful type of image compositing, where we place foreground objects into backgrounds that aren't really there. By using it repeatedly, we can produce some interesting effects.

Star Trek "beam-in" sequence
We can easily create effects like those seen in the popular TV and movie series "Star Trek", when they send a person to or from the spaceship using the "transporter". The scene involves members of the ship's crew being dematerialized atom by atom, and having those atoms sent to or from the ship, where they are then reassembled.

To reproduce this effect, we need some crew members, a planet to "beam" them to, and some sort of transition effect. I seem to recall seeing a television show where they described how the effect was created for the original 1960's series. When the crew members are "disassembled", they fade away into gold sparkles, which then fade out. This effect was achieved by first transitioning from the crew members to a sequence of gold glitter stirred through a glass of water. This was then transitioned to fade away. So let's start with these images:

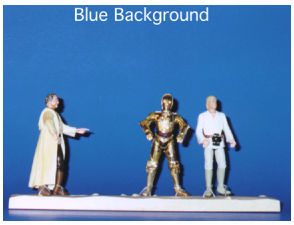

Figure 6a -The crew members

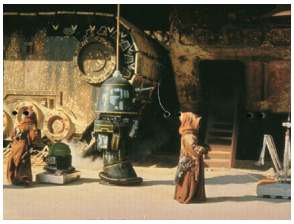
Figure 6b - The planet

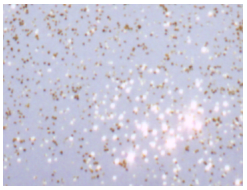
Figure 6c - The gold glitter (close up)

First, we need to extract an alpha channel from the image of the crew members. Since we filmed them against a blue background, we will use the color differencing method. This produces the matte you see below.

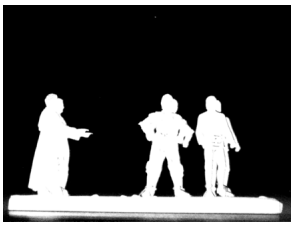
Figure 6d - The crew members' matte

Now we can create the transition from the gold glitter to the crew members, using the matte to limit which parts of the glitter show through. Here's an image from that sequence:


Figure 6e - Image from the transition sequence

Finally, we apply the "over" operator to combine the transition sequence with the background. Here are a few frames from the completed sequence:

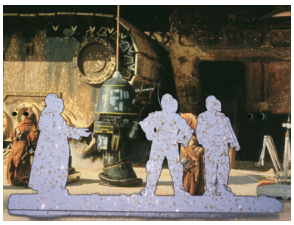
Figure 6f - Start

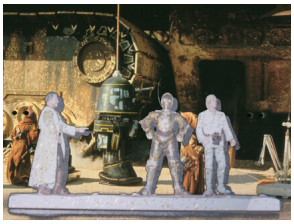
Figure 6g - Middle


Figure 6h - End

Other Uses for Alpha Channels

In addition to the traditional uses of alpha channels for compositing images, you can also use them in other creative ways. Since the alpha channel tells you which pixels of your image represent the foreground (or background), you can use it to apply effects to only the foreground (or background). For example, you invert your subject, while leaving the rest of the frame unaffected. You could make your subject black and white, while the rest is color. Or you could apply a blur to the

background to simulate depth of field effects (especially useful if your backgrounds are computer generated, and not subject to lens effects).

You can also use the alpha channel to speed up processing. If you only want to apply an effect to the subject of your scene, you can use the alpha channel as a mask. Wherever the alpha channel is 0, don't bother calculating the effect. Wherever it's not 0, apply the effect. You can even use the value of the alpha channel at each pixel as a variable in the effect, applying it more strongly where the alpha channel is brighter. If the effect you're working with does not have variables which are easily scaled (such as a convolution kernel), you can use the alpha value to mix between the original and the effected version.

Conclusions

Alpha channels allow you to do a wide variety of tasks from combining images that were not filmed together, to selectively applying effects for variety or speed. There are a number of simple techniques for creating alpha channels from images which do not already have them. When used appropriately, these techniques allow you to put together realistic and interesting scenes.

Bibliography

[Foley90] Foley, van Dam, Fiener, Hughes, *Computer Graphics: Principles and Practice*, Addison Wesley, Reading, MA. 1990

[Poynton99] Charles Poynton, *ColorFAQ*, www.inforamp.net/~poynton, December 1999

[Brinkman99] Ron Brinkman, *The Art and Science of Digital Compositing*, Morgan Kaufmann, San Francisco, CA. 1999