

Pattern Reduction in Massively Tiled Scenes

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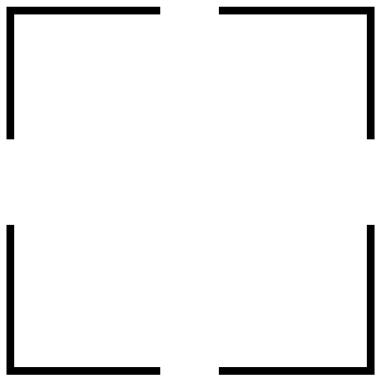
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One Microsoft Way

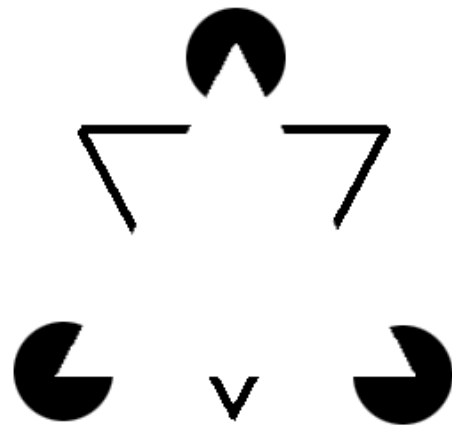
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The human brain has a phenomenal ability to find order in chaos. We use powerful pattern recognition to differentiate a known face out of a crowd of faces. Give the brain a paucity of details, and it will attempt to fill the information in on its own. Studies on the science of perception have derived the Prägnanz Law, otherwise known as the Law of Simplicity, which states that we tend to perceive the world in the simplest form possible. There are two major parts to this law: closure and grouping. Closure is the tendency to fill in missing portions from a perceptual array, or to fill in the gaps. Grouping occurs when similar or proximal elements are perceived as belonging together in a group.



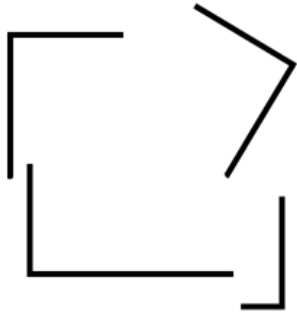
With closure, we can see a rectangle, despite gaps.



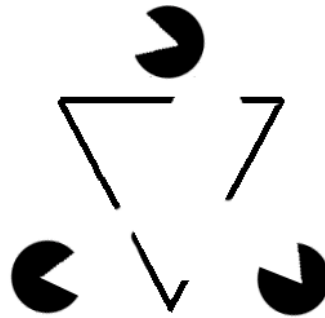
Grouping allows us to see a non-existent triangle.

These examples show that with minimal, or even incomplete, data the brain still manages to order data to fit preconceived notions. As artists, these are notions we need to be familiar with, especially when creating art for games.

While useful in real life, the process of perception can create elements in a texture that we don't want to exist. With careful consideration and execution though, we can defeat the powerful tendencies of the eye to create closure and grouping, along with other visual artifacts that tend to break a viewer's immersion. The two examples below show how a few simple modifications can overcome natural instincts of perception.



Closure broken



Grouping broken

Game art often relies on the use of tiling textures; a single image repeated over and over again. Using a single texture to cover a large area is far cheaper than using a large unique texture for every distinct object. Making a continuous toned image convincingly tile seamlessly is no small task. Even when an image does tile, an artist can still struggle with annoying repetitive elements, such as those discussed above, that cause strong vertical or horizontal view lines stretching off into infinity. As the scenery art lead and production artist on Microsoft's *Combat Flight Simulator 1.0* and *Flight Simulator 2000*, the amount of pattern repetition in a tiling texture was of paramount concern. Our textures, used to simulate terrain, would need to tile not ten, not a hundred times—but potentially thousands of times in any given scene.

The last two years and two product releases have shown a set of common issues involved in the art of pattern reduction. The following can be used as a guideline when looking to reduce patterning in any tiled texture, and introduces an additional non-art based solution as well.

1. Fundamental Themes of Repeating Textures

There are three factors to consider when first creating a tiled texture. These themes determine the degree of care and attention an artist will have to pay. As can be seen in the first point *Tile Amount*, if the texture in question is only to be tiled once or twice, less attention is needed to how much pattern results. Conversely, if the texture tiles a high degree, a great deal of care must be taken with the amount of patterning. These themes are:

- **Tile Amount**
- **Context**
- **Subject Matter**

Tile Amount

This breaks down into two points: how often will the viewers see the texture in question, and how much of the given texture will be in view? In the examples below, a brick texture is tiled in two ways. The first example (**Fig. 2**) shows a brick texture tiled three times across, and once down (3w 1 h). The texture hasn't been edited at all, yet the repeating elements are barely noticeable. In the second example (**Fig. 3**), the same texture is tiled seven times across and four times down. The texture betrays an annoying amount of patterning.

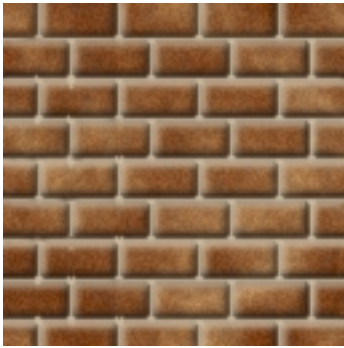


Fig. 1 The base texture

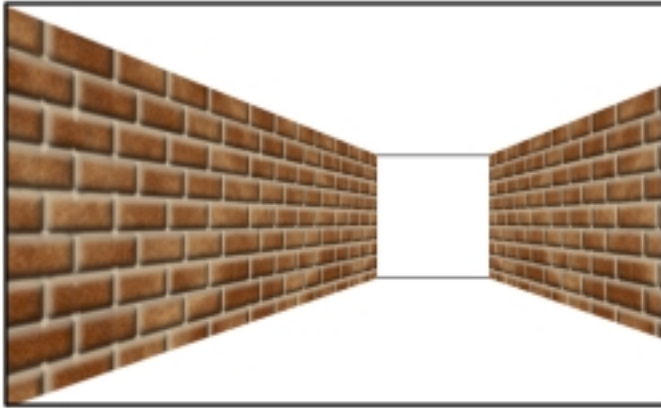


Fig. 2 The base texture repeated 3w 1h
7w 4h

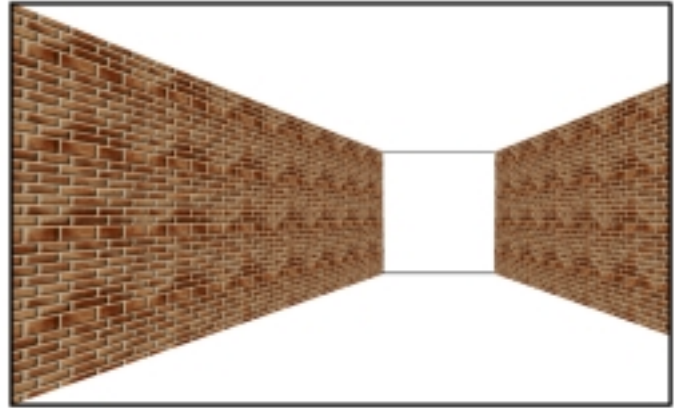


Fig. 3 The base texture repeated

Context

The environment that a texture exists in also has an impact on patterning. In a 3D environment, the addition of lighting, additional 3D objects, and other effects can both help and hinder how pattern repetition is perceived. In the example below (**Fig. 4**), the elements of **Fig. 3** are combined with other textures, lighting, and 3D objects. While the patterning is the same in **Fig. 4**, it is far less obtrusive than in **Fig. 3** where the pattern rests on its merits alone.



Fig. 4

Textures that are tiled into the distance, as in a landscape, face greater stress. Perspective cues force the eye to align along distinctive elements, as they recede into the distance. In a game space, mip mapping tends to emphasize contrast differences, creating exaggerated patterning when combined with extreme depth.

Subject Matter

The subject of a texture often dictates whether a tileable texture will have obvious patterning. A forest texture (**Fig. 5**) will likely be easier to disguise than a forest texture that also contains fields (**Fig. 6**). Care must be taken when considering how textures that have several separate distinct elements are constructed. Rather than focusing on the single instance of the texture, consider de-emphasizing those distinct features and concentrate on the overall gestalt of the image's subject.

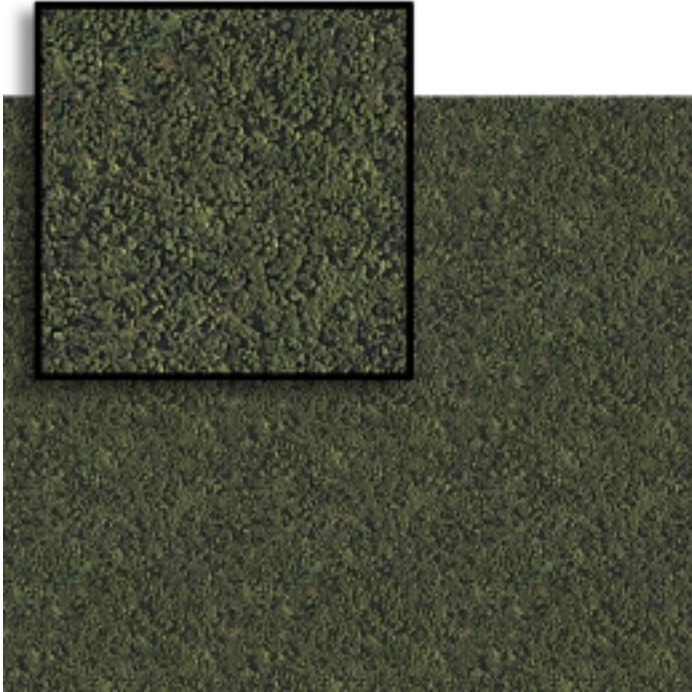


Fig. 5 forest texture

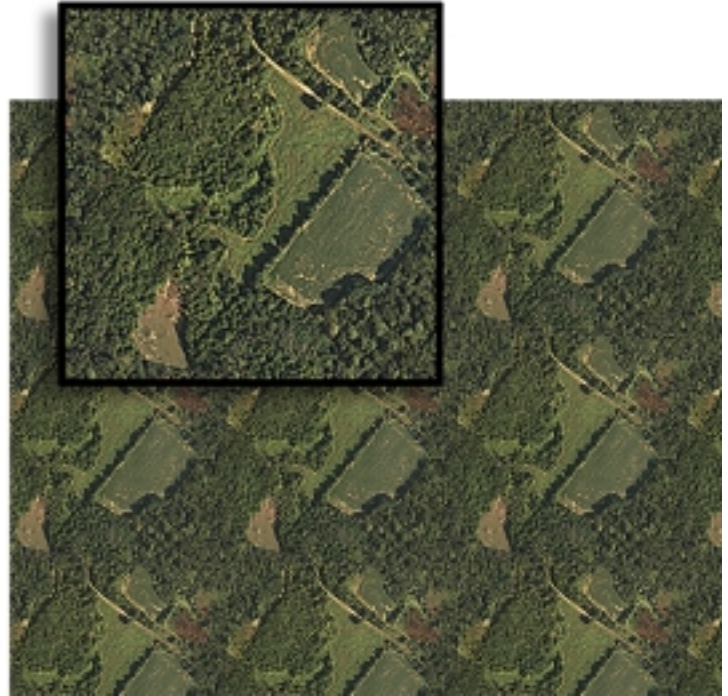


Fig. 6 forest with field

2. Areas of concentration

After considering the above themes, there are distinct areas on which the artist must focus. The overall goal in the reduction of patterning is to create textures that not only tile well, but also harmoniously inhabit the space they exist in. Tiled areas that call attention will increase the recognition of the patterning elements within. With that in mind, there are several points in the effort to reduce patterning, breaking down to the following:

- **Color**
- **Value and contrast**
- **Noise**
- **Direction**

Color

When working on a texture it's vital to ensure that the elements within have consistent color values. This is especially important when creating textures from disparate sources; piecing together a collage. Even relatively slight differences in color will be magnified when displayed in a texture with a high rate of repetition. In the illustration below (**Fig. 7**), the color difference of a few areas exacerbates the feel of pattern. When these areas are brought into a more harmonious balance of hue, saturation, and value, the patterning is less noticeable. It still exists of course, but when scanning the image, the eye no longer stops and identifies those areas as "different."



Fig. 7 color difference



Fig. 8 same elements corrected for color

Value and contrast

When looking to reduce patterning in a tiled texture, the overall value of its elements and its associated contrast level will often be the worst offending culprits. Value, a separate issue from hue or saturation, defines the levels of lights or darks in an image. Where the difference between light and dark is great, contrast will be greater. As you can see in **Fig. 9**, the closer elements are in value, the less discernable they are. Wherever possible, the value of elements in a tiling texture should be as close as possible. In **Fig.'s 10 and 11**, brick elements that differ greatly in value are brought closer together, reducing overall patterning without detracting from the subject matter. This of course can be a fine line to follow, as the subject matter of the texture may call for elements that are high contrast by nature. Nevertheless, bringing varying elements closer together in value is a key factor in overall pattern reduction. Dealing with sharp value/contrast differences is discussed in greater depth by dealing with noise.

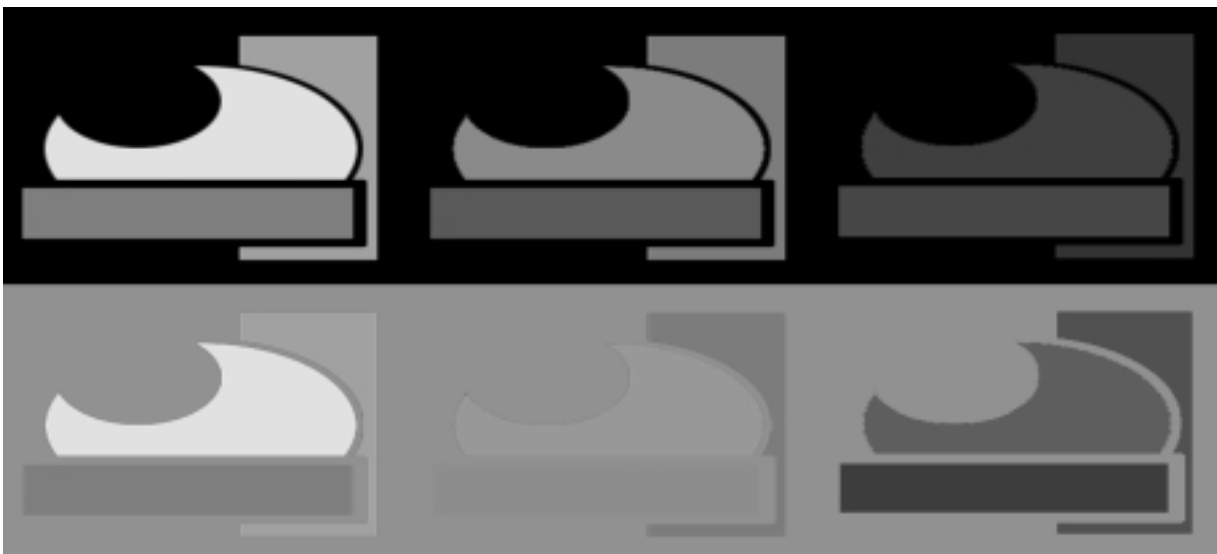


Fig. 9 Value affects contrast, causing elements to blend into the background, or pop to the front.

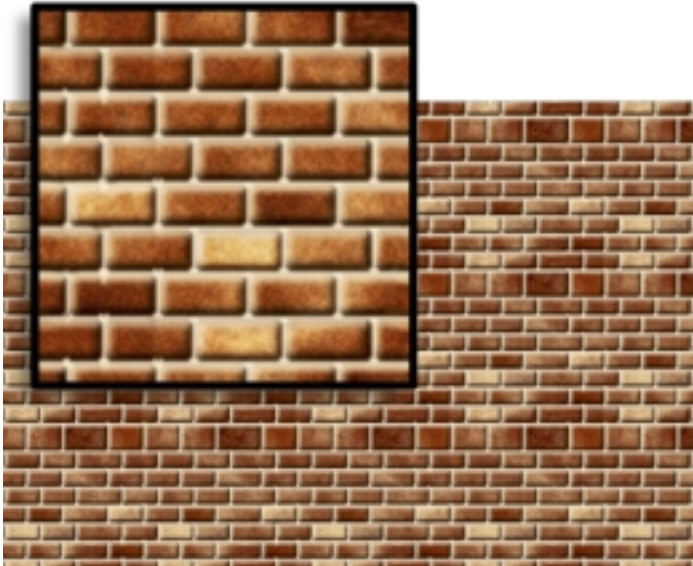


Fig. 10 Value differences cause greater repetition

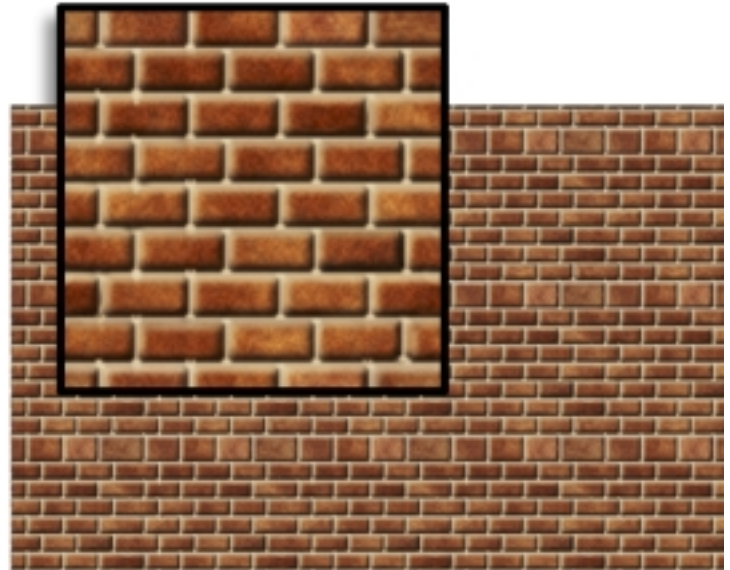


Fig. 11 Corrected values lessen repetition

Noise

Subject matter can dictate that a tileable texture contains elements with broad contrast. These visual distinctions can be subject based, as shown in **Fig. 6**, where the smooth grass fields contrast markedly with the rougher forested areas, or value based, as demonstrated in **Fig. 10**, where lighter and darker bricks cause a distinct pattern. For the artist working to lessen patterning the goal then becomes to introduce an element of noise: to distract the viewer's eye.

Fig. 12 shows a texture with three values: black, white, and middle gray. There are obvious repeating elements in this texture when tiled. **Fig. 13** shows modifications that more evenly distribute across the texture, lessening apparent repetition.

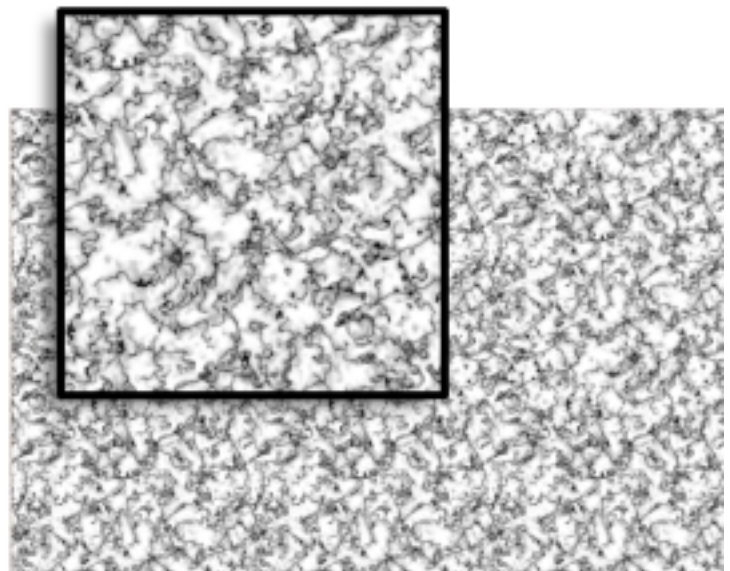
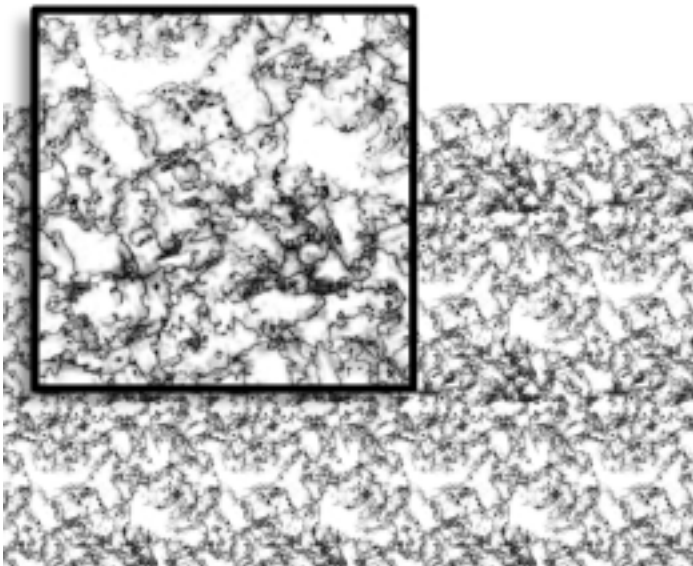


Fig. 12 Texture with distinct clumps of light and dark distribute elements

Fig. 13 Texture corrected to evenly

Direction

The bane of tileable textures is noticeable pattern repetition; an aggravating factor of that repetition is texture direction. Elements of textures that contain directional cues contribute to the striping effect seen in large tiled areas (**Fig. 14**). To effectively reduce patterning, direction must be broken. **Fig. 15** shows the strong horizontal element broken up, destroying the stripe effect seen in **Fig. 14**.



Fig. 14 Strong horizontal stripe



Fig. 15 Stripe broken up

The issues outlined above also occur on a macro scale when introduced into a complete environment, like a 3D world. By keeping the issues outlined above as consistent as possible in all your texture work, even textures that exhibit drastic patterning will be easier for the brain to accept. Differences in color, value, noise, and direction will magnify patterns and break the viewer from immersion.



Fig. 16 Two tiled textures next to each other. The differences focus the eye, magnifying the pattern.



Fig. 17 Two tiled textures next to each other. The repetition of the pattern is still extreme, but easier to accept than what is shown in **Fig. 16**

Additional notes concerning the creation of tiled textures

- Check how the texture tiles repeatedly during production.
In PhotoShop create a separate file that is a reasonable multiple of the texture you are working on. If you were working on a texture of a brick wall at 64 pixels by 64 pixels, and you knew that your texture would be tiled twice vertically and up to hundreds of times horizontally, you might create a document that was 128 pixels tall by 1024 pixels wide. Using the Edit, Define Pattern and the Edit, Fill with Pattern features you can easily check the over pattern repetition for a given texture. Also useful is viewing this pattern layout at multiple magnifications. PhotoShop makes a fair approximation of how textures will appear when mip mapped as you zoom further away.
- Be careful which tools you use in PhotoShop.
Photoshop has some great painting tools that deliver feathery edges. Unfortunately, these can leave “mushy” areas that contribute to directional patterns, especially when used along an edge. The tools you use should match your subject matter.
- Watch your edges.
When creating edges that tile, avoid long unbroken straight strokes. These will invariably show up as directional elements when the texture is tiled.

3. An Additional Solution

We use tiling textures for several good reasons: fast load time, reduced storage demands, and reduced texture memory usage. If it were possible, artists would use unique textures over icky repeating tiles any day. Until that day comes there is very little to do other than go the tile route. There is however, one final trick in the reduction of patterning--- variation.

Variation rests on the premise that while it's cheap to use tile textures, and it's very expensive to use unique textures, it's only slightly more expensive to offer a *multiple* of self tiling than it is to offer one single repeating image. In an area designated as Forest and Field that covers 100 square kilometers by 100 square kilometers, a single texture, at a resolution of 1 square kilometer, will be tiled 10,000 times. To cover that area with a unique aerial photo would require a file many times larger than the single 1km texture. To fill that same area with *seven* 1km textures, you would only have to repeat each texture about 1400 times, yet the resulting file size of all seven combined would be miniscule compared to the single 100km X 100km aerial photo. The seven textures would have the added ability to be drawn in different configurations and at different rates, lessening the amount of patterning one would see with a single tiling texture that covered seven square kilometers. **Fig. 18** shows the tiling forest texture from **Fig. 5**, but with six variations added to the layout. Each variation shares the same edges as the first texture, so each variation tiles to each of the other six.

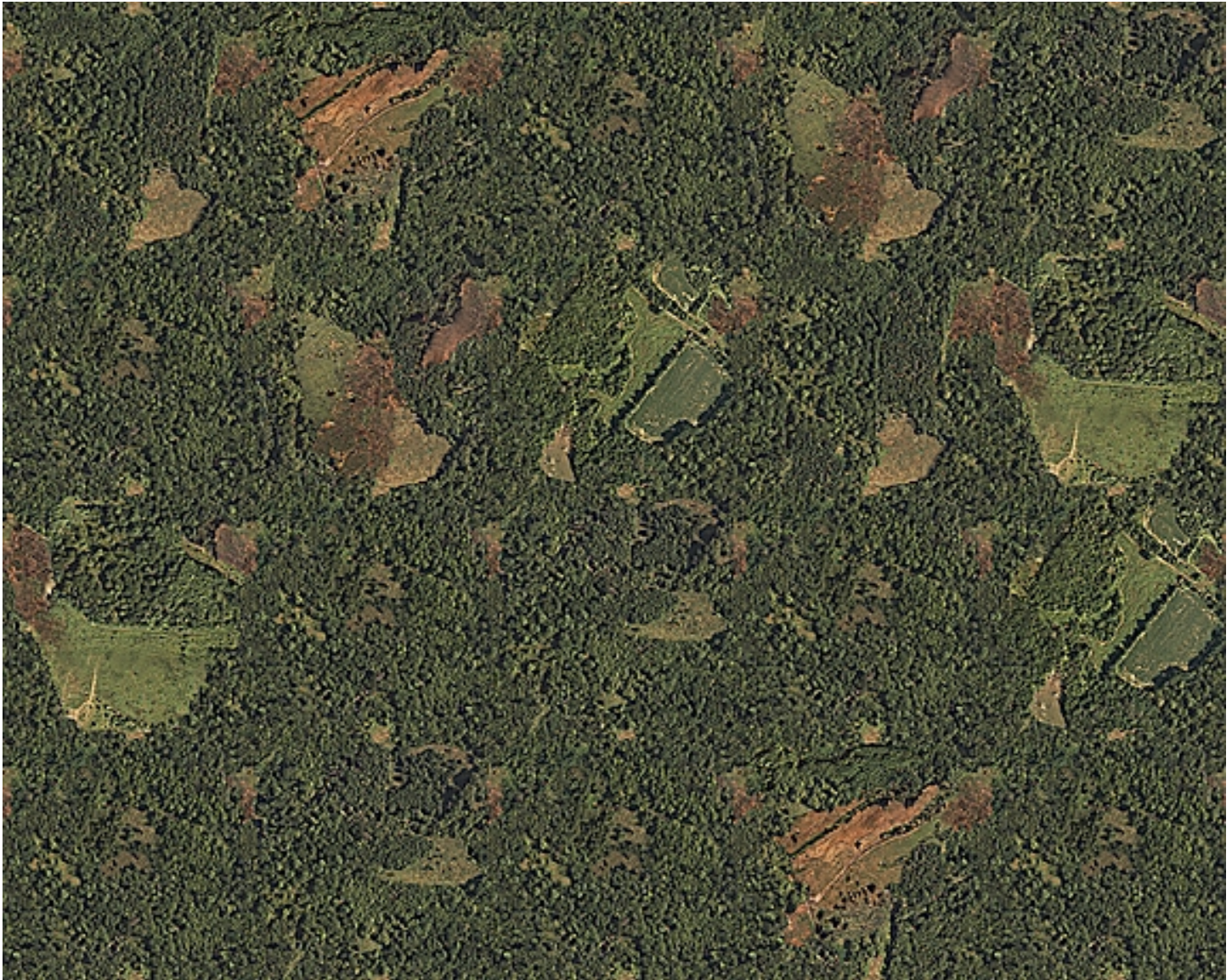


Fig. 18 Seven variations which all tile together

Note that the use of variations doesn't obviate the need to practice the fundamental areas listed above. Indeed, in some cases, they become even more important. Creating variations usually entails bringing together elements from disparate sources, and so it is crucial that the color and value of those elements be consistent across all variations. Directional elements must now be considered, as they occur across all the variations, not just within a single texture where such elements are usually easiest to control. **Fig. 18** (diagramed in **Fig. 18a**) shows that there is a strong diagonal created at the intersection of several variations.



Fig. 18a Direction cues from disparate elements.

Other considerations, like value and noise come into play as well. The introduction of variants lessens the need for absolute attention to an even distribution of noise values, as the variants themselves break up repeating clumps. As can be seen in **Fig. 18** though, variants can have elements that stand out and call attention. While the variations don't create a pattern per se, if certain elements are noticed often enough, immersion can be just as broken as with an atrociously repeated single texture. A good number of the elements in **Fig. 18** stand out. These elements would become annoying after a short time. Careful attention to the work points of color, noise, contrast, and direction to not just individual textures, but to all variations at once, will ensure a maximum effect for a minimum of textures.