

16x Fragment Antialiasing



Under NDA until May 14, 2002

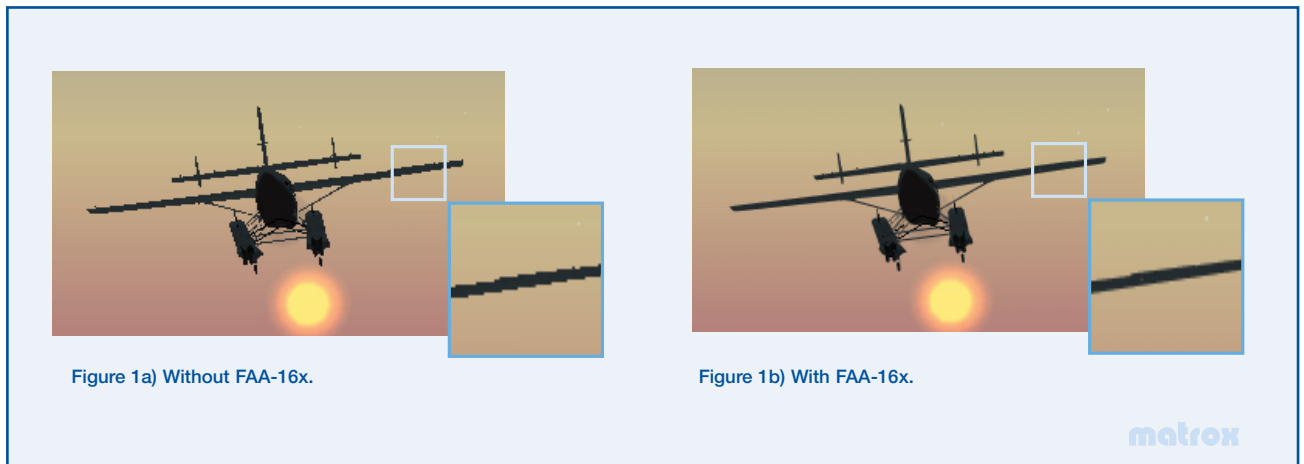
16x Fragment Antialiasing

A revolutionary approach to antialiasing, Matrox's 16x Fragment Antialiasing (FAA-16x) provides 16x super-sample quality for antialiasing to deliver the highest quality 3D rendering. By antialiasing only edge pixels, where aliasing artifacts occur, FAA-16x is able to provide this level of quality with a very small performance penalty. Applicable to many games and professional applications, FAA-16x allows users to enjoy the highest quality antialiasing available.

Introduction

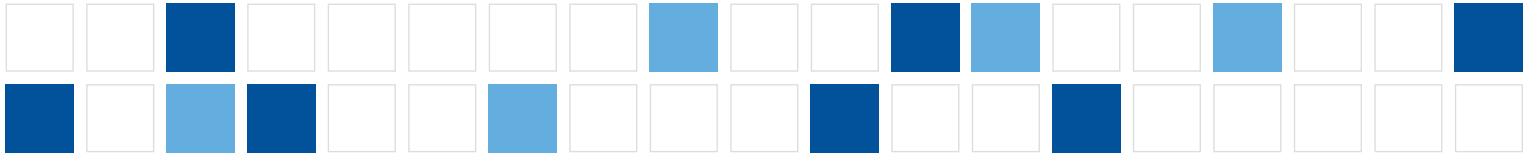
- In the past few years, there have been significant advancements in 3D graphics technology that have contributed to improving the realism and quality of 3D rendering. The most glaring visual artifacts that remain are aliasing artifacts, which refer to the staircase-like jagged pixels that are seen on polygon and line edges. Antialiasing is a method of minimizing aliasing artifacts to deliver visually smoother lines and edges.

Introduced in Matrox Parhelia™-512, 16x Fragment Antialiasing (FAA-16x) technology overcomes the inefficiencies of traditional brute-force antialiasing algorithms to deliver superior image quality without sacrificing performance. This document explains the technology behind FAA-16x and describes its advantages over existing antialiasing techniques.



A background on antialiasing

- Aliasing - often referred to as "staircasing" or "jaggies" - is the jagged-edge effect that occurs along the edges of lines and polygons. This undesirable effect happens because there are not enough pixels available on a typical monitor to properly display mathematically smooth lines and polygon edges. When a 3D scene is transposed onto a monitor's pixel grid, or raster, each pixel is colored according to whether or not it is covered by an object in the scene. Aliasing occurs because the raster system does not properly handle the case in which a pixel is only partially covered. Partially covered pixels occur along the edges of objects and are referred to as edge pixels or fragment pixels. The mishandling of fragment pixels results in harsh, jagged color transitions between an object's edge and the background. Antialiasing techniques attempt to smooth jagged edges by properly handling fragment pixels (i.e. adjusting the pixel color according to the amount of pixel coverage).



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Aliasing can be very distracting. In a typical 3D scene, made up of many objects with thousands of triangles, aliasing artifacts will be visible along the edges of all objects. Set the same 3D scene into motion, and the artifacts create a distracting swimming, or sparkling, effect that greatly diminishes the level of realism.

Aliased artifacts cannot exceed the size of a single pixel; therefore, the higher the monitor resolution, the smaller the pixels become and the less noticeable the artifacts. For example, a 1600 x 1200 non-antialiased scene will look sharper than a 1024 x 768 non-antialiased scene. The reduction in the size of aliasing artifacts is the best argument for using a higher resolution. The human eye's ability to recognize aliased artifacts is limited to approximately 600 dots per inch (dpi). Unfortunately, mainstream monitors are not able to output the resolutions required to dismiss aliasing. Effectively, the goal of all antialiasing techniques is to dampen aliasing artifacts by creating the illusion that the screen is running at a much higher resolution than it actually is.

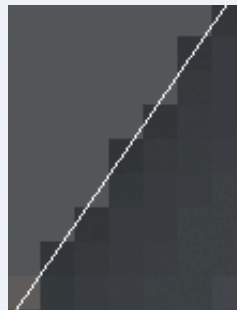


Figure 2 - Staircase effect.

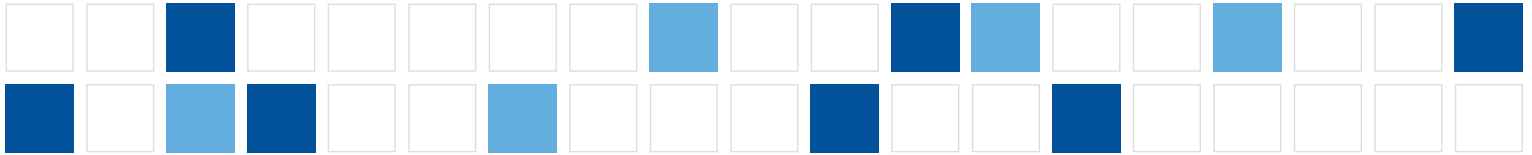
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Antialiasing techniques

- Aliasing is a complex problem because there are many triangle edges in a 3D scene that may be displayed as aliased fragments to the viewer. Since detecting fragments within a scene is a difficult task, current graphics technologies opt instead to retouch the entire scene in order to make the edges appear smoother. This technique is appropriately referred to as Full-Scene Antialiasing (FSAA). Two variations of FSAA algorithms are supersampling and multisampling.

FSAA - Supersampling

Supersampling renders an entire frame to a higher resolution and then uses the extra pixel data to obtain an improved display output. For example, 2x supersampling renders a frame to twice its required size in order to obtain two sub-pixel samples per output pixel; 4x FSAA renders a scene at four times its required size; etc. The extra pixel samples derived from supersampling are combined using filtering to produce a blended output that has a softening effect along aliased edges.



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Figure 3 demonstrates the basics of 4x supersampling. Figure 3a shows the staircasing effect that commonly occurs along edges in a non-antialiased 3D scene. Figure 3b illustrates the extra accuracy that is obtained by supersampling a scene to four times the output resolution. Essentially, for each pixel output there are four unique sub-pixel samples. These unique pixel samples are referred to as sub-pixels because they are combined to arrive at a final output pixel. The white box in Figure 3b highlights four sub-pixel samples (3/4 black and 1/4 grey) obtained through 4x supersampling. In this case, the extra sampling accuracy determines that instead of being fully covered by the dragon's wing (as is the case in Figure 3a), the output pixel is actually only 75% covered. During downscaling, the filtering operation renders a pixel, which combines the color of the edge pixel with the color of the background pixel using a 75:25 ratio. The end result, shown in figure 3c, is smoother color transitions between the edge and the background.



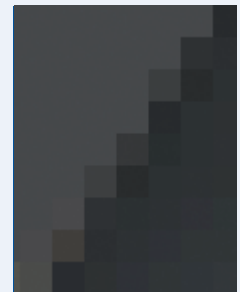
Figure 3 - Scene from 3Dmark2001.



3a) No antialiasing. The white line represents the edge of the dragon's wing.



3b) Note that there are now four samples where there used to be only one.



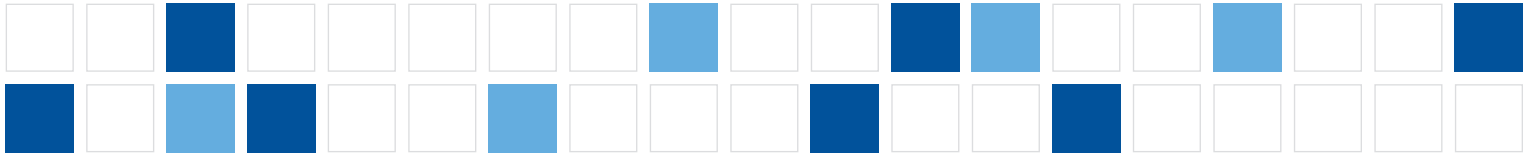
3c) 4x FSAA super-sampling combines the four sub-samples to arrive at a final output.

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There are variations of supersampling based on different sub-pixel sampling locations, but the true determination of quality is the degree of oversampling. Higher degrees of FSAA create smoother edges, because the extra sub-pixels translate into greater coverage accuracy and more shades of color for smoother edges in the final output. In short, a higher sampling rate produces a higher quality edge. A 1024 x 768 screen image with 4x antialiasing will have the same quality as a 2048 x 1536 resolution without antialiasing.

FSAA - multisampling

Multisampling antialiasing (MSAA) is an alternative to the supersampling technique used in traditional FSAA. Like supersampling, MSAA renders a scene to a higher resolution; however, it offers a slight performance improvement by reusing texture samples for the sub-pixels. For example, a 4x supersampling algorithm will fetch four unique texture samples for each of the four sub-pixel samples, whereas a 4x MSAA algorithm will select only one texture sample and reuse it four times for each of the 4 sub-pixels.



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Comments on FSAA

In order to obtain a noticeable improvement in image quality using FSAA algorithms, a minimum of 4x sub-pixel accuracy must be used; however, because FSAA over-renders all pixels in the 3D scene, it incurs a significant performance penalty. In fact, the performance penalty is so high that the current generation of GPUs are not able to exceed 4x quality and maintain reasonable performance levels. 16x Full-Scene Antialiasing output is an unreasonable request for today's GPUs.

16x Fragment Antialiasing

- FSAA and MSAA algorithms are inefficient because entire 3D scenes need to be over-rendered and filtered, even though only a fraction of the pixels in a scene actually require antialiasing. On average, fewer than five to ten percent of pixels need to be antialiased. Parhelia-512 uses the new FAA-16x technology, which takes advantage of this fact and provides 16x quality for applications with compatible 3D rendering techniques. FAA-16x intelligently detects fragments within a screen image and then resolves them with 16x supersample quality.

Figure 4 - Fragment pixels typically account for less than five to ten percent of the total number of pixels in a scene. In this 3Dmark2001 scene, 3.2% of the pixels are fragments (9850/307200).

Figure 4a

Figure 4b

Figure 4c

Figure 4d

Figure 4e

Figure 4f

4a) The aliased edge of the horn in figure 4.

4b) FAA-16x identifies non-fragment pixels from fragment pixels. Non-fragment pixels are written to the frame buffer.

4c) Fragment pixel data is segregated and written to the fragment buffer.

4d) Fragments are identified by inspecting triangle edges with 16x accuracy (4x4 sub-pixel grid).

4e) Fragment coverage and color data is stored in the fragment buffer.

4f) Fragment data is eventually resolved and written to the frame buffer to achieve a final 16x antialiased output.

Matrox FAA-16x identifies fragments by inspecting triangle edge pixels with 16x sub-pixel accuracy to determine their pixel coverage: a pixel is either not covered, fully covered, or partially covered (i.e. a fragment). This information is then used to determine whether the pixel should be discarded, placed in the frame buffer, or sent to the FAA-16x unit. All non-fragment pixels are immediately written to the frame buffer, while all fragment data is collected and stored in a fragment buffer. The fragment buffer maintains fragment lists, which contain information about a particular fragment pixel. Specifically, the fragment list stores sub-pixel coverage and color information for each of the edges that intersect the pixel. The FAA-16x unit continuously updates the fragment buffer to determine the final representation of true scene fragments. The fragments are then combined and the final pixels are written to the frame buffer to complete the frame. Figure 4 illustrates this process.



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The FAA-16x unit has been designed such that the fragment detection algorithm does not impact fill rate. Although a modest performance drop occurs due to fragment buffer bandwidth, the effect on performance is much less than both supersampling and multisampling methods while the quality of antialiasing is quadrupled.

Matrox FAA-16x's unique fragment detection algorithm identifies the fragment pixels within a scene that require antialiasing and renders all other pixels normally. The efficiency of the algorithm allows FAA-16x to sub-sample fragments with 16x accuracy — a level of sampling accuracy that requires too much bandwidth for an FSAA implementation. Using the same logic that was applied earlier, a 1024 x 768 screen image rendered with FAA-16x is equivalent to a screen resolution of 4096 x 3072. This resolution approaches the limits of the human eye's ability to notice aliasing artifacts, and yields the sharpest image quality for 3D rendering.

Since FAA-16x needs to detect edges in a scene, there are some applications that use 3D rendering techniques, which are not handled perfectly by the algorithm. However, it is important to note that these applications are few and the majority of applications will be antialiased with 16x quality using FAA-16x. In the case of the few applications that over expose the limitations of the algorithm, Parhelia-512 also supports traditional antialiasing methods (up to 4x FSAA).

Benefits of FAA-16x:

■ Highest-quality antialiased edges

- 16x sampling accuracy - an unrivaled level of antialiasing quality

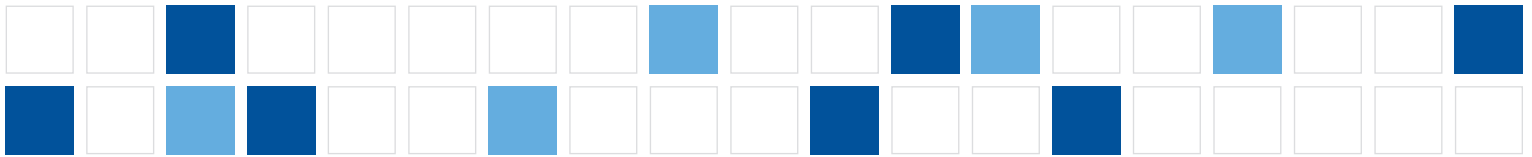
■ Preserved texture quality

- Non-fragment pixels are left untouched; therefore, texture quality is preserved
- Normal texture filtering techniques, such as anisotropic filtering, are supported by FAA-16x

■ Efficiency

- The unique fragment detection algorithm delivers high quality images with only a modest performance impact
- Less performance hit than 4x FSAA while achieving four times the quality

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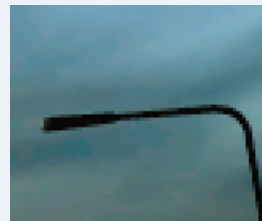
Antialiasing quality

- The following examples illustrate the quality advantages of FAA-16x compared to traditional FSAA algorithms.

Antialiasing quality - example 1



Figure 5 - FAA-16x clearly delivers a smoother and more realistic image.



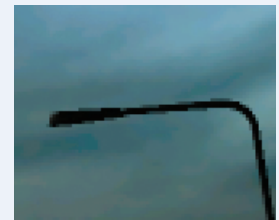
5a) FAA-16x



5b) No AA



5c) 2x FSAA



5d) 4x FSAA

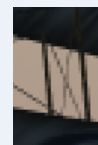
Antialiasing quality - example 2



Figure 6 - Scene from Microsoft®'s Flight Simulator 2002.

6a) The cross wires of the biplane are a good example to display the superior accuracy of FAA-16x. Notice that both the 2x and 4x FSAA examples do not have enough accuracy to properly display the thin wires without gaps. The FAA-16x example is much smoother and more realistic.

6b) Notice the extra colors along the edge of the wing in the FAA-16x example. The extra colours create a softer, more realistic edge.



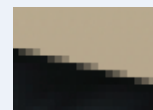
a) FAA-16x



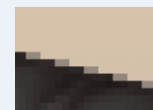
a) 2x FSAA



a) 4x FSAA



b) FAA-16x



b) 2x FSAA



b) 4x FSAA

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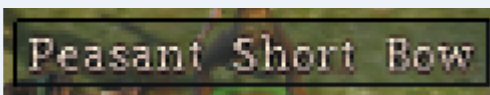
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Texture quality

- While the primary goal of an antialiasing algorithm is to reduce unnatural jagged edges, the secondary concern is to preserve texture quality within the rest of the scene. Matrox FAA-16x maintains a scene's texture quality because it does not affect fully covered, non-fragment pixels. FAA-16x delivers the same, or better, inner texture quality as other FSAA techniques.



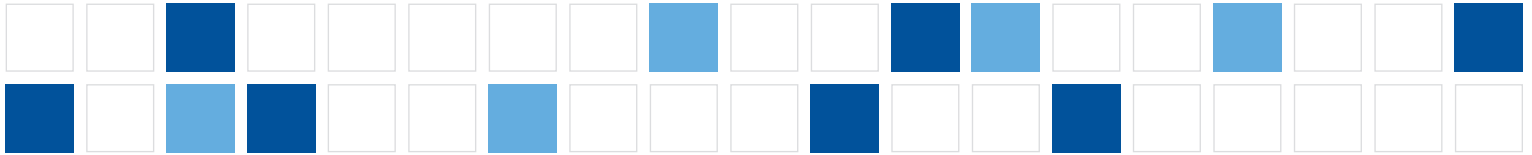
Figure 7 - Notice the heavy blurring in the multisampling example as compared to FAA-16x. While only a few examples have been highlighted, the blurring is visible across the entire scene (scene from Microsoft® Dungeon Siege).



7a) FAA-16x

7b) Some Multisampling techniques

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Performance

- Historically, the usage of antialiasing has been hindered by the poor performance characteristics of antialiasing algorithms. FSAA has been supported in previous generations of GPUs, but for the most part it has been ignored due to unacceptable performance. Only recently have GPU speeds allowed FSAA algorithms to become useable in games and applications.

The key significance of FAA-16x technology is that it delivers 16x antialiased quality with greater efficiency than traditional 4x FSAA. The inefficiencies of traditional FSAA algorithms have prevented current GPUs from exceeding 4x quality with reasonable performance. Matrox's FAA-16x overcomes the inefficiencies of FSAA by treating only the pixels in a scene that actually require antialiasing. The result is greater antialiasing precision on fragment pixels at a relatively low performance drop of 20 - 30 percent.

Conclusion

- Supporting Parhelia-512's goal to deliver the highest-fidelity graphics, 16x Fragment Antialiasing (FAA-16x) delivers the sharpest antialiased image quality during 3D rendering. FAA-16x successfully overcomes the inefficiencies of traditional brute-force antialiasing methods to deliver 16x quality without compromising texture quality or performance.