Multiple Image Suppression
in a
Low-Cost Visual System

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ABSTRACT

To maximize display resolution, scene density, and image quality at an affordable cost, the U.S. Army Close Combat Tactical Trainer (CCTT) employs a 15Hz image update rate visual system. When operating at this low image update rate, visual anomalies occur which hinder the training task. Multiple imaging is one of the most serious visual anomalie observed in a low update rate visual system. Multiple imaging negatively affects image resolution, and can cause loss of situation awareness, and in some cases, simulator sickness. A technique, called Multiple Image Suppression (MIS), is used in the Commander's Popped Hatch (CPH) panoramic display in the CCTT visual system to significantly reduce the negative effects of multiple imaging.

This paper introduces the reader to the artifacts of multiple imaging that result from an image update rate that is less than the display refresh rate. It describes the side effects that can occur as a result of using Multiple Image Suppression. It describes the Multiple Image Suppression technique as implemented in the image generator and used on the Commander's Popped Hatch panoramic display of the M1A1, M1A2, and M2A2/M3A2 manned modules on the CCTT program. This paper explores the cost and performance benefits of Multiple Image Suppression. And finally, the paper examines expanded uses of the Multiple Image Suppression technique.

ABOUT THE AUTHOR

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INTRODUCTION

With each new generation of image computing technology, suppliers compete to provide the best imagery at the lowest cost. The definition of "best imagery" is subjective, but it is generally accepted to mean the highest display resolution (i.e. best pixel performance), the maximum scene density (i.e. best polygon performance), and the finest image quality (i.e. sub-pixel sampling, image antialiasing, texturing, and shading), at a 60Hz image update rate or higher.

Unfortunately, not all applications can afford this definition of "best imagery." For each application the most cost-effective use of image rendering resources is achieved at the lowest update rate acceptable to the target application. This assures the maximum object density and greatest scene complexity at the lowest cost. Ground combat simulators have placed a particularly high value on low cost, but the inherent scene density in a ground environment requires an extremely dense scene. To satisfy these conflicting objectives, ground combat simulators have historically operated at image update rates between 15Hz and 30Hz. In ground warfare tactical trainers, like SIMNET and CCTT (Close Combat Tactical Trainer) a 15Hz image update rate is accepted. For precision gunnery training, a minimum of 25-30Hz has been considered essential. The U.S. Army PGT (Platoon Gunnery Trainer), and COFT (Conduct of Fire Trainer) systems, and the AGTS (Advanced Gunnery Training System) operate at 30Hz.

Nevertheless, the "best imagery" is obtained when the image is computed and displayed to the eye at a rate of 60Hz or higher. The challenge facing suppliers today is to deliver new techniques that provide the user with the best imagery at an affordable cost.

One method applied today on the CCTT program is Multiple Image Suppression (MIS). The Commander's Popped Hatch (CPH) panoramic display of the M1A1, M1A2, and M2A2/M3A2 manned modules employ's Multiple Image Suppression to reduce the artifacts of multiple imaging. This post-render, image-shifting technique provides improved image resolution when the scene is slewing across a display, and reduces the likelihood of simulator sickness. Multiple Image Suppression approximates the quality of a 60Hz image update rate at the cost of a 15Hz image update rate system.

This improved performance is not without limitations. Some visual side effects can be introduced into the image when Multiple Image Suppression is used. To properly exploit the Multiple Image Suppression technique, the technical trades must be understood and the technique applied under the appropriate conditions.

The following paragraphs describe the visual anomalies of a 15Hz image update rate system, explain the artifacts seen in multiple imaging, and introduce the technique of Multiple Image Suppression. The discussion continues with a description of the side effects that can occur as a result of using Multiple Image Suppression. The cost and performance benefits of the apparent higher update rate system, as used in the CCTT Commander's Popped Hatch panoramic display, are explained. The paper concludes with a discussion of expanded use of the Multiple Image Suppression technique.

LOW UPDATE RATE VISUAL ANOMALIES

To understand the visual anomalies caused by low image update rate systems two terms must be understood: *display refresh rate* and *image update rate.*

The *display refresh rate* is the number of times per second that the rendered image is refreshed on the display device. In the visual simulation community, 60Hz (60 images per second) is widely accepted as the minimum display refresh rate required in the depiction of daylight imagery. This is to avoid flicker of the image which can cause eye fatigue and other negative effects. The time necessary to refresh the display once is referred to as a *field*. For the purpose of this discussion a 60Hz or greater display refresh rate is assumed essential.

The *image update rate* is defined as the number of times per second that a new scene is computed and rendered into the frame buffer of the image rendering system. The image update rate is always equal to, or an integral multiple of the display refresh rate. For example, when the display refresh rate is 60Hz, the image update rate is either 60Hz, 30Hz, 20Hz, 15Hz, or 7.5 Hz. The time required to render a single image is referred to as a *frame.*

Having an image update rate lower than the display refresh rate manifests no visual anomalies when the image is static. In other words, when the image eyepoint is not moving (translation or rotation) and there is no movement of objects within the scene, no visual anomalies will be observed. However, when the image update rate is lower than the display refresh rate, and there is any motion in the image, a few anomalies can be observed: object stepping, image stepping, and multiple imaging.

Object Stepping

Object stepping is defined as an incremental spatial discontinuity in the continuous motion of an object moving through the rendered image. Specifically, it is the discontinuity in motion caused by the object's position being computed and displayed at a rate where the discrete displacement is visible to the viewer.

Erratic or spastic motion of objects within the rendered image may result from inconsistencies in image update rate, or from discontinuities in eyepoint or vehicle movement. Erratic motion of the image caused by systems that do not operate at constant update rates, as may occur during image processing overload, will not be discussed. In a well-designed simulation visual system, pixel and polygon processor load management techniques seldom allow overload to occur. Also, with the emergence of low-cost distributed network simulation, a significant amount of the erratic behaviors of the vehicles in the visual scene are due to dead reckoning and network latencies. For the purpose of this discussion I will ignore inconsistency in movement due to temporal or spatial errors in the computed location of an object. Smoothing of vehicle motion and time rectification can be performed to minimize the negative effects of dead reckoning and network latencies. I will focus only on the anomalies of a low image update rate. However, these sources of erratic motion must be addressed in the final ready-to-train system.

When a low image update rate is used in the visual rendering system, as in the 15Hz image update rate in CCTT, three predominant sources of object stepping can be easily identified.

One source of object stepping occurs when the eyepoint of the simulated vehicle is moved (translated) through the simulated world. Objects in the rendered image appear to step as the eyepoint moves past the objects. Objects near the eyepoint appear to move through the image faster than objects in the distance. The relative motion of objects based on viewer movement and distance to the object is referred to as parallax. A simple analog in the real world will help reinforce the concept that translation of the viewer's eyepoint produces a significant amount of relative motion within the scene. As you drive down the road, you can easily observe how quickly the sign posts and road signs pass by your peripheral vision, while the sun or moon off in the distance seems to exhibit almost no movement at all. This is object stepping caused by translational movement of the viewer's eyepoint.

A second source of object stepping occurs when the ownvehicle eyepoint is stationary (no translation or rotation) in the simulated world and other simulated vehicles are moving. These other vehicles may appear to step within the image depending on the distance from the viewer to the other vehicles and the rate of motion of the other vehicles. More specifically, the discrete displacement of a vehicle is visible to the viewer based on the distance to the vehicle and the distance moved by the vehicle in a single frame. Consequently, vehicles near the viewer appear to step more than vehicles in the distance. This object stepping is caused by translational movement of other vehicles.

A third source of object stepping occurs due to motion in the image that is related to changes in object shape. Motion, such as observed in a simulated explosion, may appear to grow in size in discrete steps. The change in motion of the simulated explosion appears no faster than that of the image update rate. This is object stepping caused by shape changes of the object.

Object stepping can be observed at all image update rates that are lower than the display refresh rate. Stepping anomalies are more pronounced at the lower image update rates, such as 15Hz. Stepping can be reduced at a 30Hz image update rate and practically eliminated at a 60Hz image update rate.

However, if the displacement of the object is extremely large in a single frame, it appears to step even at a 60Hz image update rate. This is because the moving object is computed at discrete intervals. At near distance, a fast moving object only appears at a few positions in the image as it moves through the scene. This does not provide the necessary stimulus to perceive continuous motion, even at a 60Hz image update rate. If the object motion could be presented to the eye as a blur of the object, as would naturally be perceived, the object would not appear to step.

Image Stepping

Image stepping is defined as an incremental spatial discontinuity in the continuous motion of the rendered image. Specifically, it is the discontinuity in motion caused by the image position being computed and displayed at a rate where the discrete displacement is visible to the viewer. When the ownvehicle eyepoint is at a fixed location (no translation) in the simulated world and the vehicle is rotating, image stepping is observed. The entire image steps to each new location, based on the rate of the rotation.

This type of stepping is an artifact of simulation. A real vehicle moves within the real world; however, in the simulator the simulated world is "moved" around the simulated vehicle. For example, when the turret is commanded to turn, the simulated turret does not move, the imagery on the fixed location display is "moved" to simulate the turning of the turret. The image stepping is caused by rotational movement of the viewer's eyepoint with respect to the simulated world.

Image stepping is observed at all image update rates that are lower than the display refresh rate, and is even observed at a 60Hz image update rate, if the rotation rate is extremely high.

Multiple Imaging

Multiple imaging is a physiological visual artifact which occurs when the viewer becomes fixated on a stepping object in a stationary image or on a stepping image. Multiple imaging is the perception of multiple replications of the same image, each slightly shifted from the other, observed when viewing a moving object or image in which the update rate is less than the display refresh rate.

In the case of image slewing, as the image moves across the display, the observer's eye intuitively tracks the objects in the image. Each time the image rendering system updates the scene, the new image appears at the exact position expected by the tracking eye; however, the intermediate refreshed images are also presented at this same position on the display. Because the eye continues to track at the rate of the moving image, the repeated images are focused on different areas of the retina. The result is the perception of replicated images. The separation between these replicated images increases as the apparent velocity of the image motion increases. The number of replicated images is the ratio between the display refresh rate and the image update rate. A display refresh rate of 60Hz and an image update rate of 30Hz result in double imaging; a display refresh rate of 60Hz and a 15Hz image update rate result in quadruple imaging. In CCTT, a display refresh rate of 60Hz and an image update rate of 15Hz results in four separate replicated images.

Multiple imaging is most frequently observed when the entire image is slewed across the display, but can also be observed when an object is moving within the image.

Slewing Images: In ground-based training systems multiple imaging is most noticeable during angular movement (slewing) of the simulated image. This is because ground vehicles have relatively low speeds (translational velocity) compared to their rapid turning rates (rotational velocity). In fact, for most ground vehicles the observed image motion is a result of slewing the turret or turning the vehicle. Even an independent sight like the M1A2 CITV, which is used to scan for targets, generally pans from

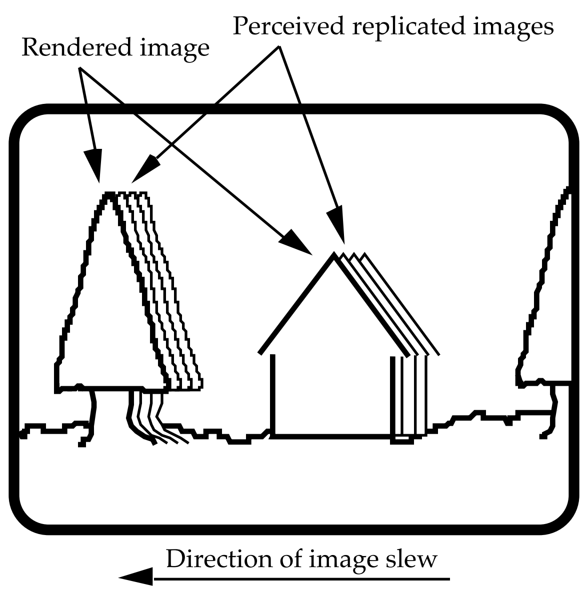

Figure 1. *A simulation system which operates with an image update rate lower than its display refresh rate suffers from the negative effects of multiple imaging.*

side to side, producing rapid rotational motion. Figure 1 depicts the artifact of multiple imaging in a 15Hz system caused by slewing. Note that the initially rendered image is observed to be repeated three additional times at different locations to the observer's eye.

Moving Objects: Multiple imaging of moving objects can be observed in systems where the update rate is less than the display refresh rate, whenever there is constant relative motion within the image. When a vehicle moves across a stationary image and the eye tracks the vehicle, the viewer may observe multiple imaging of the vehicle. This type of multiple imaging will be most noticeable when the target vehicle is crossing the scene perpendicular to the line of sight. This is the same effect that occurs when the image is slewed due to turret rotation. The eye tracks (fixates on) the moving vehicle, and since each of the three additional intermediate images are rendered in the same location on the display, the eye perceives the vehicle to be four places on the retina. Figure 2 depicts the multiple imaging of a moving vehicle in a stationary image, with a 15Hz image update rate.

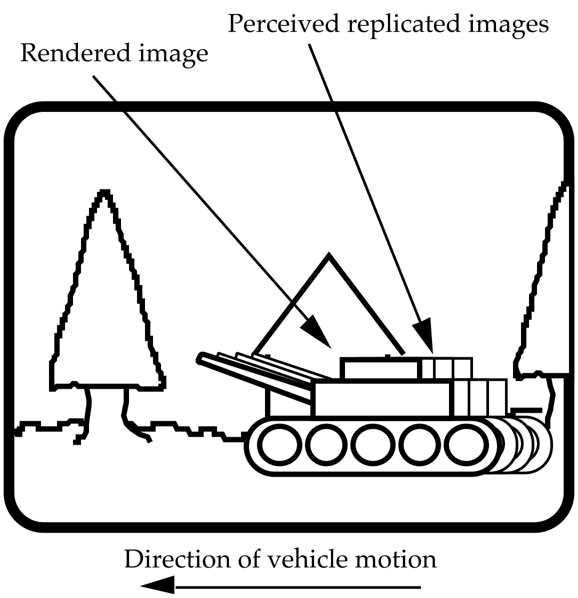

Figure 2. *Target stepping caused by target motion in a stationary image.*

Negative Effects of Low Image Update Rates

Multiple imaging, object stepping, and image stepping can cause both degradation in image resolution and simulator sickness.

Resolution Degradation: Multiple imaging results in a dramatic degradation of image resolution. The higher the rate of image motion, the lower the image resolution. In fact, when the replicated image displacement is as little as 25% of the static image resolution, the image resolution begins to perceptibly degrade. This means that when the displacement of the replicated image is only a fraction of a pixel, resolution is degraded. This image resolution continues to degrade as the rate of image motion increases.

The result of image stepping and multiple imaging due to slewing of the image, is a dramatic decrease in target detection, recognition, and identification ranges. The degraded resolution simply reduces the range in which details in the image can be resolved.

The result of object stepping and multiple imaging, due to object motion in a stationary eyepoint image, is an artificial increase in target detection range and a decrease in target recognition and identification ranges. In a stationary image, a slow moving target may be detected easily in a low update rate system because it's motion is more pronounced due to object stepping. Yet, when the target is tracked it will multiple image, the resolution will degrade, and the viewer will struggle to recognize or identify the target.

It is important to understand that this degradation in image resolution is similar for all image update rates that are less than the display refresh rate. That is, an image update rate of 30Hz and 15Hz will experience a similar degradation in resolution at the same angular slew rate. This is because the image displacement is a function of the rotation rate of the viewing eyepoint image, not the image update rate.

Simulator Sickness: Simulator sickness is also of major concern with low image update rate systems. Object stepping, image stepping, and multiple imaging are very severe in moving eyepoint systems and are potential causes of simulator sickness.

Another source of simulator sickness is the disparity in sensory cues due to system latency. I will not discuss this concern, but it must be addressed in a low update rate system.

Object stepping and multiple imaging of objects moving in a stationary eyepoint image are troublesome to target detection, recognition, and identification, but are not likely to be the cause of simulator-related sickness.

Image stepping and multiple imaging due to slewing is very unnatural and can cause viewer disorientation, confusion, nausea, and feelings of vertigo. Concern over simulator sickness in the large panoramic 360° Commander's Popped Hatch panoramic display on the CCTT M1A1, M1A2, and M2A2/M3A2 manned modules motivated implementation of Multiple Image Suppression. A significant number of viewers reported feeling dizziness and nausea as a result of the demonstrations that took place while prototyping the panoramic Commander's Popped Hatch. We identified the image stepping and multiple imaging in the moving eyepoint image as the source of the dizziness and nausea.

MULTIPLE IMAGE SUPPRESSION

Multiple imaging can be avoided by assuring that the image update rate matches the display refresh rate. This is the solution used in most flight simulators in service today, and the solution that technology trends point to as the long-term answer to the multiple imaging problem.

However, utilizing this solution for CCTT would require increasing the cost of the image rendering system by a factor of four, or degrading the resolution and scene complexity by the same factor of four. An alternative is to provide a method that can eliminate the artifacts of the low image update rate without significantly increasing the cost of the image rendering system.

Multiple Image Suppression is a technique designed to reduce the artifacts of multiple imaging caused by image slewing with minimal impact to processing performance. Essentially, the image rendering system over-computes a slightly enlarged horizontal field-of-view image each processing frame. Figure 3 depicts this over computed image. When image slewing is introduced into the computed scene in response to rotational inputs from the host computer, the direction and magnitude of the motion is computed. This motion information is processed in the image rendering system using an interpolation algorithm to determine the incremental change required in the image for each of the intermediate refresh fields during the update frame. The displayed image is shifted appropriately within the over-computed image to accommodate the change in viewing direction in each display refresh frame.

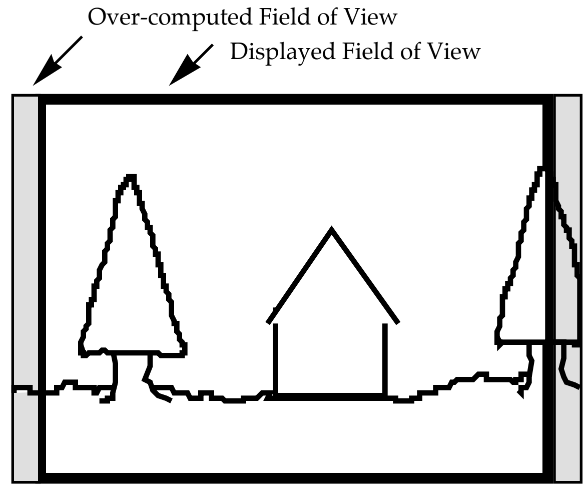

Figure 3. *The field of view of the displayed image is over computed such that the image can be shifted to provide correct placement of the intermediate images between image updates.*

The computed field of view must be large enough to cover the field of view currently being displayed and also the surrounding field of view which could be visible before the next image update. The size of the over-computed field of view is a product of the maximum slew rate for which multiple imaging must compensate. The size of the additional field of view defines the performance impact of implementing Multiple Image Suppression.

The information necessary to shift the image is sent directly to the frame buffer so that placement of the current image and the next image is exactly known. Interpolation in image position provides placement of the intermediate images. This assures that the intermediate images are in the correct location, as if they were computed at the display refresh rate. This interpolation (rather than extrapolation) also allows for compensation of acceleration in image slewing and provides correct control of the intermediate images even in polygon or pixel processor overload conditions. Interpolation is possible because the command to control image shifting is sent to the frame buffer in approximately one frame, while the data to render the image takes approximately two frames. The location of the next frame is known before the previous frame is rendered. The interpolation algorithm correctly computes the intermediate image position at all times, failing only under the most extreme polygon or pixel processor overload conditions.

MULTIPLE IMAGE SUPPRESSION TECHNOLOGY TRADE

Multiple Image Suppression is not without side effects. Understanding the limitations of Multiple Image Suppression was key to its successful application on the CCTT program.

Commander's Popped Hatch Display Analysis

As noted earlier (and prior to incorporation of Multiple Image Suppression), a significant number of viewers reported feeling dizziness and nausea as a result of demonstrations in the prototype Commander's Popped Hatch panoramic display. This raised concern that a 15Hz update rate would be unacceptable to the CCTT users. A detailed, pre-contact analysis of all of the CCTT viewing devices revealed a number of key observations.

First, when viewing from the design eyepoint of the Commander's Popped Hatch display, the only physical spatial reference for the viewer comes from the image presented on the ring of surrounding monitors. This means that all spatial references, including peripheral vision, are provided by the computed imagery. Consequently, when the imagery is moving, and multiple imaging occurs, a stable spatial reference is lost. This was the source of the simulator sickness.

Second, multiple imaging does not induce dizziness and nausea in the prototype vision blocks that were operating at the same 15Hz image update rate as the Commander's Popped Hatch. This is because only a limited amount of the viewer's field of view is occupied by the computed imagery. The spatial references are provided by the mechanical structure of the vision blocks and surrounding fixtures.

Third, when the image is slewing, the loss in resolution is observed in all of the display devices as a result of multiple imaging. This was the primary source of the loss in target detection, identification, and recognition range.

Fourth, the loss in dynamic resolution is less dramatic in the magnified sights than expected. There are two reasons that appear to contribute to this effect: limited slewing rate and object of focus. It was observed that the operator did not slew the magnified sight faster than is possible to assure a focused image. That is, the operator limited, perhaps artificially, the slew rate to avoid multiple imaging. It was also noted that the magnified sight slewed side to side across the area of regard while searching for targets. Once a target is acquired, side to side slewing stops and the sight is used to track the target. More importantly, the object of focus changed from the background to the tracked target. While tracking the target, the target is held centered in the sight, and the multiple imaging of the background objects is no longer noticed.

Fifth, multiple imaging was more noticeable in built-up areas of the visual database. This was due to the many sharp edges, particularly in the buildings. Forest and grassland areas were less distracting when multiple imaging occurred.

Sixth, the higher the resolution of the computed image, the more noticeable the loss of resolution at smaller rotational and translational velocities. This is due to the relationship of the static resolution to the degradation from the displacement.

With a reasonable understanding of the cause of the simulator sickness, we determined that it was vital to suppress multiple imaging in the Commander's Popped Hatch panoramic display. Obviously, we could not artificially limit the slewing rate of the turret or the turning rate of the vehicle, and the cost of adding image computational resources to allow a higher image update rate was prohibitive. However, because the primary motion of the ground vehicle viewing devices is slew, the implementation of the Multiple Image Suppression appeared the ideal solution. Multiple Image Suppression is used in the Commander's Popped Hatch panoramic display to keep costs down, while eliminating the negative artifacts of multiple imaging. However, like a doctor's prescription, the cure may have some side effects.

Multiple Image Suppression Side Effects

We observe two side effects in the CCTT Commander's Popped Hatch implementation of Multiple Image Suppression: jitter of the ownvehicle model in a slewed image, and jitter of moving objects in a slewed image.

Ownvehicle Model: Objects in the image which are fixed with respect to the display inherit the compensation movement removed for the background scene. The ownvehicle model used to provide the illusion of viewing from atop the vehicle is one such object. The ownvehicle model is in a fixed position with respect to the display device. Hence, when the image is moving and Multiple Image Suppression is employed, the background scene is stable but the ownvehicle image jitters. I use the term jitter to denote that the observed motion is a back and forth motion, almost like a vibration. This side effect is very distracting when viewed for the first time, but when considered in the context of how we use the Commander's panoramic view, it appears to be an acceptable trade.

The Popped Hatch panoramic display provides the Commander with a comprehensive view of the area surrounding his vehicle. From the Popped Hatch, the Commander can survey the landscape and search for targets. The landscape and targets are much more important than the foreground ownvehicle model. Initial results indicate that the jitter in the ownvehicle is noticed only in the first few moments of the simulation. Within seconds, the primary focus of the training takes over and the ownvehicle jitter is never considered again.

Moving Targets: Objects in the scene that are moving perpendicular to the line of sight inherit the compensation movement removed from the background scene when the image is slewed at or near the translational rate of the target object. This side effect observed in the Commander's Popped Hatch is actually due to the actions of the gunner, or coincidence between vehicle motion and image slewing.

To understand this side effect, we need to look at the visual anomalies apparent when tracking a target in a low image update rate visual system. When a vehicle is moving across the scene perpendicular to the line of sight, and the image is stationary, the vehicle exhibits multiple imaging as described earlier in this paper and illustrated in Figure 2.

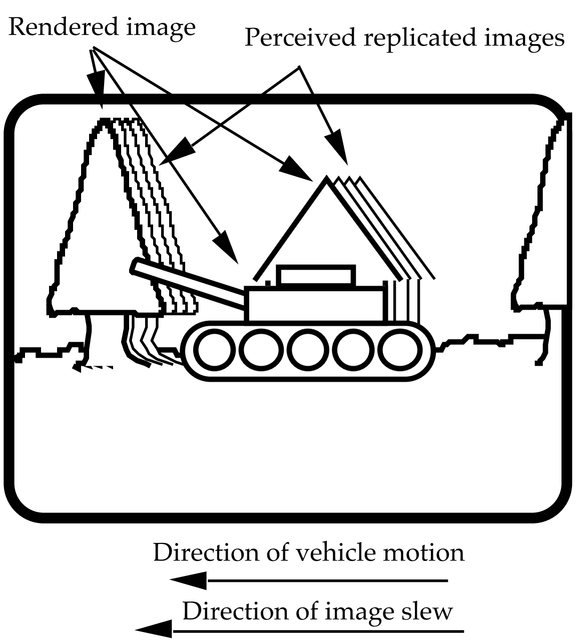

Figure 4. *Background stepping when a moving target is tracked, without Multiple Image Suppression.*

However, in a magnified sight the vehicle is not ordinarily allowed to simply move across the scene, but in fact, the magnified sight is slewed to track the moving vehicle. The object of interest, in this case a vehicle, is maintained in the center of the image. Without Multiple Image Suppression, the target is appear clear and crisp in the center of the display, and the background exhibits multiple imaging. This artifact is illustrated in Figure 4. Note that the moving target is held relatively motionless in the center of the image while the background is "moving" behind the vehicle.

When Multiple Image Suppression is active in the Popped Hatch panoramic displays, and this condition occurs, the moving vehicle target inherits the compensation movement removed from the background scene. This condition is illustrated in Figure 5. Note that the tank is shifted forward in the direction of the image slew. The magnitude of the jitter is a function of the target's speed and range to the observer.

With the low speeds of ground vehicles, and the typically long engagement ranges, this inherited stepping is seldom large enough to be distracting. In the Commander's Popped Hatch display, this is a very low probability of occurrence artifact, and consequently, it is accepted as a good trade for improved target detection, recognition, and identification in the typical operation.

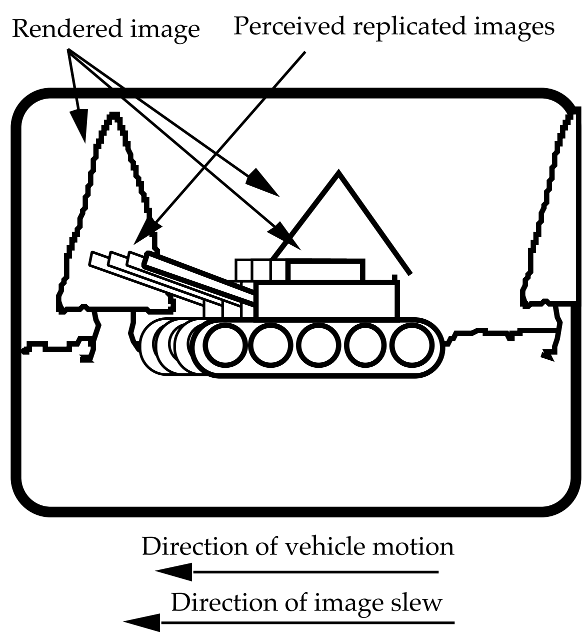

Figure 5. *Target stepping caused by Multiple Image Suppression when the image is slewed at the rate of the target movement.*

The use of Multiple Image Suppression in the Commander's Popped Hatch panoramic display makes a very cost-effective trade for CCTT. At the cost of a 15Hz system, we approach the image quality and resolution of a 60Hz system and reduce the possibility of simulator sickness.

OTHER APPLICATIONS OF MULTIPLE IMAGE SUPPRESSION

To date, Multiple Image Suppression has been employed only in the Commander's Popped Hatch panoramic display of the manned modules of the CCTT systems. However, other applications seem inevitable as improved performance is demanded at lower costs. Multiple Image Suppression can be used to improve the performance of the magnified sight and vision blocks.

Vision Blocks

By providing the additional polygon and pixel processing resources needed to over compute the image, each vision block could utilize Multiple Image Suppression, with fundamentally the same set of trades found in the Popped Hatch panoramic display system. This would improve the resolution of the vision block when the vehicle imagery is slewing.

Magnified Sights

The performance can be similarly improved for the magnified sights. In addition to compensating for slewing, Multiple Image Suppression is also capable of supporting pitching movement of the image. Compensating for multiple imaging in both slew and pitch has been shown to significantly improve the ability of the gunner to resolve detail in the scene while panning side-to-side, and pitching up and down.

However, to add Multiple Image Suppression to the magnified sights, a few more technical trades must be understood.

In the CCTT modules, the reticles are rendered in the image along with the background image. To add Multiple Image Suppression to the magnified sight the symbology can no longer be rendered within the background imagery. Symbology, like the ownvehicle mentioned earlier, is static with respect to the display. The sight symbology can be provided using a post-render, post-image-shifting image-mixing process. This will totally avoid the symbology interacting with the Multiple Imaging Suppression. This enhancement is being evaluated for insertion into the CCTT magnified sight.

As noted in the discussion regarding the side effect of Multiple Image Suppression and illustrated in Figure 5, when a moving target is tracked in a magnified sight, Multiple Image Suppression can degrade the resolution of the target. Jittering in the target reduces the target's recognition and identification range. At typical engagement ranges, and typical speed targets, and with current technology magnified sights, this jitter will not be observed. However, to eliminate this negative side effect the Multiple Image Suppression can be disabled when a target is being tracked. Techniques to accomplish the activation and deactivation of Multiple Image Suppression based on natural operator actions are under evaluation.

CONCLUSION

Suppliers continue to develop faster and less costly image rendering systems, and users continue to demand higher display resolution, finer image quality, and increased object density, all at the highest image update rate possible. But until technology can affordably recreate the real world at 60Hz, techniques like Multiple Image Suppression must be employed to get increased performance for less money.

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