zmicro

+ IMPROVE SITUATIONAL AWARENESS w/REAL-TIME ENHANCED VIDEO

The military relies on video imagery for situational awareness, but image quality is often so poor that operators can miss important details. Image processing algorithms that improve image clarity in real time provide better visibility for more informed decision making.

The backbone of modern defense capabilities, Intelligence, Surveillance, and Reconnaissance (ISR) relies on a robust and diverse network of integrated sensors, aircraft, and manpower. The value of this network ultimately relies on human capability to clearly see sensor imagery, discern important details, and take decisive action. In the field, we have little or no control over the lighting and environmental conditions under which images are acquired from a sensor. Using ZMicro's advanced image enhancement technology, it is possible to give more control to the person viewing live sensor imagery, by allowing them to enhance video imagery and fine-tune it on the fly to pull out more information.

There are innumerable tactical situations where good visibility is critical and the use of enhanced imagery could significantly reduce risks and increase mission successes. Consider, for example, American warships patrolling the waters of the Persian Gulf at the Strait of Hormuz where dust, morning fog, and haze can make visibility especially difficult. The strait is narrowest at about 30 miles in where it is recognized as a naval choke point that has been the scene of stand-offs in the past. As multiple vessels approach, the ability to see clearly enough to distinguish hostile targets from friendly or neutral vessels is essential. Similarly, ground vehicles driving through a dusty environment kicking up dust make it difficult to see ahead, and in some cases impossible to identify whether an approaching vehicle is friend or foe. Another instance where image enhancement could significantly improve safety is helicopter brownouts. During near-ground flight, and in particular during take-offs and landings in the dessert, helicopter rotor downwash can stir up intense, blinding dust clouds that can prevent pilots from seeing nearby objects which provide the outside visual references necessary to control the aircraft near the ground. The ability to see clearly through dust, fog, rain, smoke, haze, glare, etc., is crucial to mission safety and success.

Enhancing live imagery in real time requires sophisticated image processing techniques and tremendous computational throughput. It requires applying these techniques to incoming video streams without introducing delays. ZMicro has developed real-time video image enhancement technology that implements advanced image processing techniques as algorithms that run on high-performance field-programmable gate arrays (FPGAs). FPGAs provide an ideal processing platform because they allow sophisticated image processing algorithms to be implemented in hardware, which is much faster than software. ZMicro's image enhancement algorithms can be applied to incoming live video streams to produce dramatically better clarity. It gives operators greater control over imagery, including the ability to home in on important details to uncover information necessary for informed decisions.

CLARITY IS IN THE EYE OF THE BEHOLDER

Full-Motion Video (FMV) is the tool of choice for military situational awareness. Automated video recording is featured on virtually all military vehicles, including manned vessels such as fighter jets, trucks, and tanks, as well as Unmanned Aircraft Systems (UAS). Producing high-quality imagery on a mobile platform poses a number of challenges. In addition to issues related to camera motion and the resulting image perspectives, the quality of the video imagery can also be compromised by poor environmental conditions, data link degradations, and bandwidth limitations. Atmospheric factors such as poor lighting at dawn, dusk, or nighttime, and adverse weather, including sand storms and variable clouds can obscure important details.

Sensor image quality, however, is not the only problem. The conditions under which a video is viewed vary widely and thus present another set of challenges. For example, video streams may be viewed in bright sunlight, underwater, or in a dark cave with a headlamp shining on the screen. In these situations, there is a distinct advantage in providing image enhancement capability within the display itself, rather than at the sensor or elsewhere on the network.

The only way to ensure a good image quality is to give the viewer the ability to adjust the picture for their needs. The best way to accomplish this is to bring real-time video enhancement to the tactical edge. ZMicro's FPGA-based image enhancement technology offers the performance, design flexibility, and resilience needed to provide this capability.

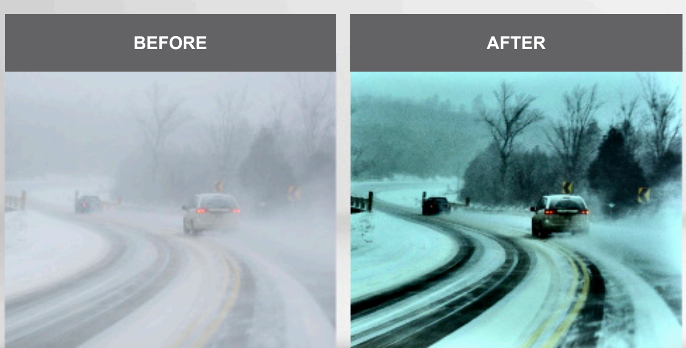
Applications such as those described above can benefit from using ZMicro's image enhancement capability which is available in the following ZMicro product families: 1) Intelligent Display Series; 2) ZView, a standalone "set-top-box" that allows enhancement algorithms to work with any monitor; 3) ZMicro custom integrated technology or user installable retrofit kits that add image enhancement capability to pre-existing customer equipment such as display, cameras, or computers.

ZMicro also offers the capability to tag video streams with metadata using its ZVideo software suite which supports real-time encoding, ingestion, playing, clipping, annotation and distribution of digital video assets. For example, when an operator identifies a target, the metadata could be tied to the video stream allowing future cross-reference and location of that spot in the video. Key features of ZVideo include management of video content, task scheduling, recording video from multiple analog or digital sources, and creating multi-layered metadata annotations including text, voice, and graphics.

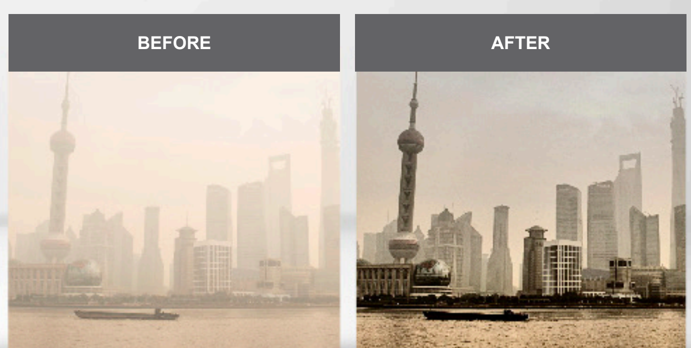
ALGORITHMS ARE COMPUTATIONALLY INTENSIVE

Anyone familiar with photo editing programs, such as Adobe Photoshop, can appreciate the power of software algorithms for enhancing still images. Using sophisticated software algorithms to apply mathematical functions to the image matrix, it is possible to reveal hidden layers of visual information without losing detail. This is a purely mathematical approach that utilizes all of the available image information, including portions that are not normally visible to the human eye.

SEE WHAT YOU'VE BEEN MISSING



Underwater video typically exhibits degradation due to the scattering of light due to the water. RTEV pulls the details of underwater objects out and clarifies difficult to see objects.



Smog obscures important information in video preventing you from seeing all the variations in the scene. RTEV excels in smoggy video as it highlights the details otherwise washed-out.

RTEV KEY FEATURES

LOCALLY & GLOBALLY ADAPTIVE ALGORITHMS

RTEV can leverage both globally adaptive and locally adaptive algorithms. Locally adaptive algorithms look at each pixel individually and with respect to its surrounding neighborhood, it decides how to transform that pixel accordingly. Globally adaptive algorithms look at the statistics of the whole image to determine what adjustments to make and then applies the result globally to the entire image.

PLUG & PLAY ARCHITECTURE

RTEV can be integrated into virtually any pre-existing system. Users have the option to keep their existing video display equipment and use our compact standalone appliance to enhance incoming video streams. Alternatively, users can purchase one of our rugged displays with built-in RTEV. RTEV video enhancement technology works on any type of video feed and outputs the same resolutions as received.

NO ADDED LATENCY

RTEV technology is real-time video enhancement with no added latency. The enhancement algorithms are written to utilize parallel processing and leverage Field Programmable Gate Array (FPGA) to support image processing algorithms in hardware. The latency is measured in microseconds and provides no latency to the human eye.

Over the past decades, a large body of image processing algorithms have been developed using techniques including histogram manipulation, convolution, morphology, over- and undersampling, quantization, and spectral processing, including Fourier transforms and Discrete Cosine Transforms (DCTs). These algorithms tend to be computationally intensive. Conventional processor technology does not offer the performance necessary to keep up with the demands of FMV at up to 60 frames per second (fps), or one frame every 16.67 milliseconds. Processing a Standard-Definition (SD) video stream requires about 150 to 200 gigaflops, while a 1,080p stream requires about 1.2 teraflops. This is where FPGAs shine, first and foremost because they implement the algorithms in hardware, which is always faster than software. In contrast, CPUs and GPUs run software, which takes more time because instructions have to be fetched and cued up, math operations have to be performed, and results have to be sent to memory. FPGAs offer deterministic performance, with latencies that are an order of magnitude less than that of GPUs. Furthermore, FPGAs require less power because they use parallel processing and, therefore, can achieve required performance at lower clock frequencies than software processors.

When image enhancement algorithms are written to utilize parallel processing techniques and ported to an FPGA, it becomes possible to apply one or more image processing algorithms to live video streams in real-time. ZMicro has developed a collection of advanced image processing algorithms that can be applied individually or in combination to dramatically improve image clarity and visibility in a wide variety of applications.

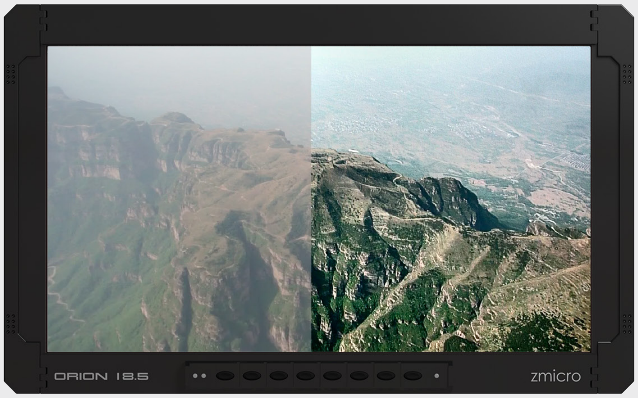
FINDING A NEEDLE IN A HAYSTACK

ZMicro’s approach to image enhancement is to make it easier for viewers to see whatever it is they are looking for. The goal is not necessarily produce pretty pictures, but rather to be able to discern important details that would otherwise be missed. Perhaps it is hard to see due to interference from environmental factors such as fog, rain, or smoke. Or maybe the area of interest is too dark, or at the other extreme blindingly bright. ZMicro strives to give the viewer the tools necessary to see the big picture and to then drill down into specific areas for greater details.

Since a camera is capable of capturing much more information than the human eye can see, the goal of the image algorithms is to bring out the information that is important to the viewer and make it more visible. Much of the eye’s ability to discern information is due to its capacity to perceive a difference in luminance i.e. perceived brightness. Changes in luminance create a pattern of contrast, and it is the contrast that conveys the majority of visual information we see. Consider, for example, the rod sensors in our eyes are about 100 times more sensitive to luminance than are the color sensitive cones. Additionally, we are better at detecting changes in contrast rather than

CUSTOMIZED ENHANCEMENTS

Customize your video enhancement to achieve the best settings for your application using the on-screen display (OSD) menus built into our rugged displays and video enhancement systems or configured using an attached PC running our Graphical User Interface (GUI) or by using our Application Programming Interface (API) commands.



absolute luminance values. Thus, contrast does not equate to brightness, rather it is a difference in brightness. In the context of local contrast, if there are two objects that are both a gray, but one is a little darker than the other, then there is not very much local contrast between them. Contrast in a global sense is the range in contrast seen access the entire image.

The role of contrast is especially important when imagery is viewed on computer displays. Given a choice, most people strongly prefer images of higher contrast. Therefore, it is not surprising that all of ZMicro's image processing algorithms are designed to improve visibility by adjusting contrast in various ways.

ZMicro has developed a collection of advanced image processing algorithms that can operate either individually or in combination. When a user enables image processing, the enhancement can be applied to the entire viewing screen or it can be limited to only a sub-window designated by the user. There are no hard and fast rules for choosing one specific algorithm or any particular combination of algorithms for a given application. This is because there is such wide variation in the quality of imagery, including the conditions when it was collected and the circumstances when it is viewed. Additionally, user preferences are somewhat subjective. ZMicro uses its expertise and experience to offer a number of preset algorithm configurations and tunings that allows a user to quickly cycle through the options to find the best setting. Presets can be created to adjust for a wide range of conditions including haze, fog, snow, clouds, night, underwater, dusk/dawn, glare/blinding light, helicopter brownout, dust, rain, pollutants, smoke, low-light, over exposure, over saturated, mist, spray, infrared (IR), electro-optic (EO), 3D, contrast enhancement, increase resolution, and so on.

ZMicro also offers the tools that enable users to customize system settings using a configuration utility, or to programmatically access algorithms using an application programming interface (API). There are basically five types of algorithms implemented in ZMicro's products which include 1) histogram-based, 2) clarifier, 3) edge detection, 4) global dehaze, and 5) sharpener. All of these algorithms perform their enhancements by operating on the image matrix to directly manipulate pixels within the image.

ZMicro's algorithms are self-adjusting, meaning that the specific processing applied to an image is based, to some degree, on the information contained in the source images. The algorithms are either globally adaptive or locally adaptive.

GLOBALLY ADAPTIVE ALGORITHMS

Global adaptive algorithms first look at all the data in an image as a whole and depending on the characteristics of the data, the algorithm will do something differently based on what it finds. For example, a globally adaptive algorithm would look at the statistics of the whole image to determine what adjustments to make, and then apply the result globally to the entire image. Histogram equalization is a good example of a globally adaptive algorithm. A histogram is basically an accounting of pixels within an image frame that occur at each of the different brightness values. If brightness ranges from 0-100, for example, there will be 100 different bins, and each pixel in the image will be counted into one of the bins. Histogram-based algorithms are considered globally adaptive because as the algorithm is assigning pixels to a bin, the location of individual pixels relative to other pixels in the image does not matter, the algorithm simply tallies all the pixels in the whole image. Then, if the histogram shows that there are a lot of dark pixels, for example, and not many very bright ones, the algorithm will adjust the gains so that the bright pixels get made brighter. It is globally adaptive because it works on groups of pixels at the same time. It takes all

RTEV ALGORITHMS

EXPANDED SHARPENER
Sharpening with an adjusted 11x11 kernel size to bring out image details and reduce undesirable noise.

CLARIFIER
Locally adaptive, ultra-large convolution kernel for improved contrast and overall visibility.

TRUE COLOR
Globally adaptive dehazing algorithm designed to remove the detrimental effects of haze, fog, smoke, mist, dust and bring out the color in degraded video.

ALL ALGORITHMS
When used together, each algorithm provides a complementary enhancement feature that lets you extract more value from your video and gain the confidence to make critical decisions faster.

the pixels that were in bin 23, for example, and makes those 47 instead, and so on, without regard to where specific pixels are located in the image. Histogram equalization tries to flatten the entire histogram so that if there are a majority of pixels that are in the dark and not so many in the bright area, it takes some of the dark ones and spreads them out. Equalization taken to the fullest would wind up with all the bins equally populated.

Another example of a globally adaptive algorithm is global dehaze. The global dehaze was designed to take into account the physical processes that go along with atmospheric haze and fog, and the different types of scattering of light underwater or similar phenomena. It tries to take into account the physics of the situation with regard to particular obscuring media that come between the object and the camera. Is it based on knowledge and experience with how different media typically affect the light in terms of treating different wavelengths, or different colors differently, e.g., preferentially using more of the blue or the red, and so on. It then attempts to organize the reconstruction of the image in ways that make sense with the physics in the situation. Like histogram-based algorithms, global dehaze looks at the statistics of the data from the entire image, decides what types of corrections to make, and then applies those corrections by doing the same operation to the entire image. The difference is that it with global dehaze, the gains and offsets applied tend to be more linear because the processes in the physics that degrade image data are correspondingly linear, and the algorithm attempts to mirror those effects.

LOCALLY ADAPTIVE ALGORITHMS

In contrast to globally adaptive algorithms, locally adaptive algorithms look at each pixel individually and with respect to its surrounding neighborhood. Based on the statistics of what's going on in that neighborhood, it decides how to transform that pixel accordingly. Then it moves to the next pixel and does the next transformation, and so on until it has processed all of the pixels in an image. For example, a pixel might have a brightness level of 23, and based on its surrounding neighborhood the algorithm maybe decide to change it to a 47. Somewhere else in the image, there may be another pixel whose value is 23, but based on is surrounding neighborhood, the algorithm determines it can do a better job of enhancing by changing that 23 to an 82.

Other locally adaptive algorithms include edge detection and image sharpeners. ZMicro's edge detection uses a Sobel operator that works by calculating the gradient of the intensity of the image at each point, finding the direction of the change from light to dark, and calculating the magnitude of the change. The magnitude of the change indicates to how sharp the edge is. Edge detection tends to create an image which emphasizes edges and transitions.

Image sharpeners, on the other hand, use a Laplacian operator designed to enhance the higher spatial frequencies while simultaneously suppressing lower frequencies. The algorithm is particularly good at finding the fine detail by removing blurring and highlighting edges in an image. ZMicro offers an extended sharpener that can both sharpen and smooth images at the same time to further improve clarity.

Locally adaptive image processing is typically done using a mathematical operation called a convolution kernel. While the underlying mathematics of convolution filtering are complex, performing an image convolution operation is straightforward. A convolution kernel generates a new pixel value based on the relationship between the value of the pixel of interest, and the values of those that surround it. In convolution, two functions are overlaid and multiplied by one another. One of the functions is the video frame image and the other is a convolution kernel. The frame image is represented by a large array of numbers that are pixel values in x- and y-axes. The convolution kernel is a smaller array, or a mask where values are assigned based on the desired filtering function, for example, blur, sharpen, and edge detection. The size of this array, referred to as kernel size, determines how many neighboring pixels will be used to generate a new pixel. In convolution, the kernel operates on the image to create one new pixel each time the mask is applied, and, therefore, the operation must be repeated for every pixel in the image.

THE CLARIFIER

Convolutions are computationally intensive and, therefore, most implementations use only small kernels (3 x 3, 9 x 9, 16 x 16). However, using unique, nontraditional programming techniques, ZMicro is able to implement very large convolution kernels that produce dramatically better results. The reason a very large kernel produces better results has to do with the range and variations in brightness over a given area, which is referred to as spatial frequency. By considering the data in a large neighborhood that is centered around each pixel as it is being processed, a large kernel includes a much greater range of spatial frequencies. Traditional small kernel processing can only enhance details in the very highest spatial frequencies, which typically contain little of the spectral content (full range of color) of the image, and where noise is prevalent. Hence, small kernel processors must employ high gain to have much noticeable effect on the image. High gain tends to produce sharp outlining artifacts and increases visible noise. Large kernel processing (operating on much more of the “meat” of the image) can produce dramatic results with much lower gain, with the additional benefits of large area shading, yielding much more natural-appearing images with increased local contrast, added dimensionality, and improved visibility of subtle details and features. ZMicro has developed a convolution algorithm that uses a very large 400 x 400 kernel and is designed to clarify the image by removing haze and enhancing image detail. This clarifier algorithm is able to achieve remarkable clarity by removing environmental distortions to reveal more of the real image. It improves dynamic range and contrast.

COMBINING ALGORITHIMS

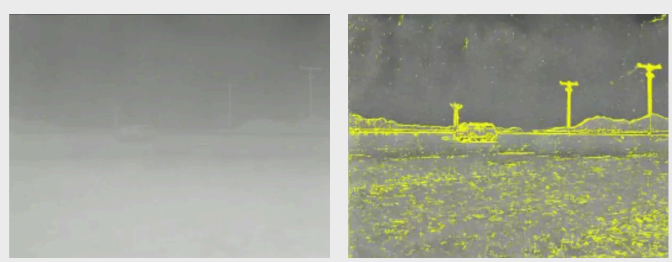
In many types of imagery, the clarifier on its own will provide excellent results, especially when the imagery already contains deep color. The clarifier produces remarkably clear images and brings out detail better than histogram algorithms. However, it does not improve color and if there is not sufficient color in the source imagery, the clarifier may produce images that appear washed out. Therefore, in some cases, it is useful to first apply the global dehaze algorithm before using the clarifier.

The global de-haze algorithm is good at enhancing color and especially useful with water, haze or fog, or other situations where there is not much color. It does, however, take some skill on the part of the user to get the best results. This is because the users need to select a window size and location carefully to avoid very bright or dark spots that can degrade enhancement results. To help avoid the problem of outliers, users also have the option of using an implicit window that allows them to select a sub-window from which the algorithm will gather the statistics it uses to determine an adjustment that will then be applied to the whole image.

When using the global de-haze with another locally adaptive algorithm such as the clarifier, it is usually preferable to apply it first. This is because, by its nature, it attempts to undo what the physics of the haze or other distortion did to the light initially. If we were to run the

CUTTING-EDGE ALGORITHMS

ADAPTIVE TEMPORAL NOISE REDUCTION (ATNR)
Improves image quality by eliminating undesired artifacts, which results from the normal operation of the camera sensors in various environments. ATNR implements advanced techniques which enable it to filter out noise without adding blurring to moving objects.



EDGE DETECTION
Helps highlight man-made objects in video streams. This can be useful, for example, in search and rescue missions at sea, or recognizing target locations in a military strike, or spotting markers during visual navigation.

locally adaptive clarifier first, it would destroy the very information that is necessary for the global operation to undo the physics. After the global dehaze removes environmental distortion, then the clarifier locally adaptive algorithm will be even more effective working at improve the visibility of low local contrast features of the image.

When applying multiple algorithms, a logical ordering might be to first clean up the atmospheric distortion by applying a global algorithm to the whole image, and next zero in on detail with local algorithms. For example, after running the global dehaze, it might be useful to next run the extended sharpener, which sharpens edges and improves backgrounds, then run clarifier, and last run edge detection. Of course, there will be some exceptions, but generally this will yield best results. Usually, it makes sense to run edge detection last because running the other algorithms first makes the edge detection job easier. A table listing the algorithms developed by ZMicro, including a description of each algorithm can be found in the Appendix.

SEE WHAT YOU'VE BEEN MISSING

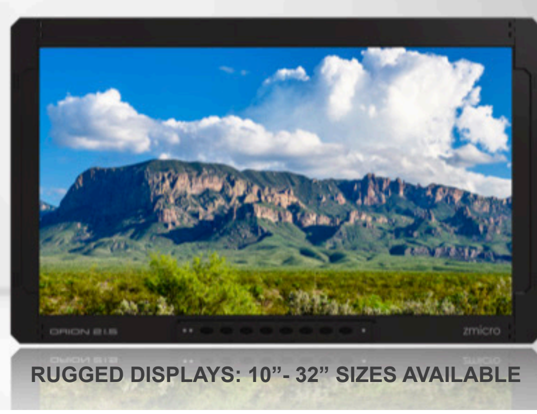
ZMicro's image enhancement technology was developed for military ISR and is now used in applications including in medical, surveillance, broadcasting, transportation, maritime, forestry, astronomy, forensics, aviation, and research applications. ZMicro has the in-house expertise to adapt its visualization technology to address a wide range of real world challenges. Image enhancement capability is available in ZMicro's full line of visualization products including standalone imaging systems, intelligent displays, visual arrays, and custom products. These products can withstand harsh environments and meet exacting military requirements for ruggedness, temperature tolerances, reliability, and a guaranteed long product lifespan. Like all ZMicro products, visualization solutions can be built-to-order and customized to meet application requirements. ++

APPENDIX - ZMICRO IMAGE ENHANCEMENT ALGORITHMS

Clarifier	Locally adaptive, very large adjustable kernel (as much as hundreds of pixels by hundreds of lines). Increases local contrast of small and moderate sized details/objects with respect to their own surroundings; suppresses unwanted large-area "background" variations, for improved visibility e.g., simultaneously in areas of glare & shadows.
Edge Detection	Presently implemented as Sobel-filter-based edge highlighting.
Expanded Sharpener	Greatly Expanded version of Sharp-like algorithm implementation. Adjustable 11 x 11 kernel; sharpens and/or smoothens, e.g., can reduce highest spatial frequencies and simultaneously emphasize an adjustable band of frequencies just below the smoothening. Also can suppress "background" variations, but with different (higher) spatial frequency characteristics than Clarifier. (NOTE: Sharpener and Expanded Sharpener are mutually exclusive, not sensible to be used together)
Global Dehaze	(Globally Adaptive Dehaze) Matches dynamic range, improves global contrast based on data in active area. Can be tailored specifically to remove (potentially wavelength-dependent) effects of atmospheric or other scattering and absorption, e.g., from haze, fog, smoke, water, etc., consistent with applicable dispersive radiative transfer models. Note that the Global Dehaze designation in the above table refers to a previous variant of this basic algorithm that was targeted for dynamic range adjustment in monochrome imagery (e.g., IR).
Histogram Equalization	(Globally adaptive – Histogram Equalization). Matches dynamic range, improves global contrast based on data in active area. Remaps image color intensities to spread output values more uniformly over the entire available output intensity range. (NOTE: Histogram Equalization, Histogram-based Stretch and Global Dehaze are mutually exclusive, not sensible to be used together)
Histogram Stretch	(Globally adaptive – Histogram-based Stretch). Matches dynamic range, improves global contrast based on data in active area. Remaps image color intensities for improved visibility and presentation.
Sharpener	5x5 kernel; can be set to either sharpen (high spatial frequency (edge and detail emphasis) or smoothen (for noise reduction).

RTEV PRODUCTS

INSIGHT SYSTEM



RUGGED DISPLAYS: 10"- 32" SIZES AVAILABLE

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