Digital Detail Enhancement (DDE)

The performance of an IR imaging system is often classified by its detection range. This of course makes a lot of sense for security & surveillance systems as the user will want to know how far he will still be able to "see" or detect an object such as a man or a vehicle. In practice however, it can be very hard to detect targets even though they are within the theoretical limits of the system. One often neglected factor is the problem that high dynamic range scenes cause. Even if the system can resolve the target it can not be displayed to the user unless the user knows exactly within what part of the signal span the target is hidden. This will increase the time to detection significantly or even worse: it will let certain events go undetected.

What is DDE?

FLIR Systems has developed a powerful algorithm that helps the user overcome the problem of finding low contrast targets in high dynamic range scenes. This algorithm is called Digital Detail Enhancement (DDE). DDE is an advanced non linear image processing algorithm that preserves details in high dynamic range imagery. This detailed image is enhanced so that it matches the total dynamic range of the original image, thus making the details visible to the operator even in scenes with extreme temperature dynamics.

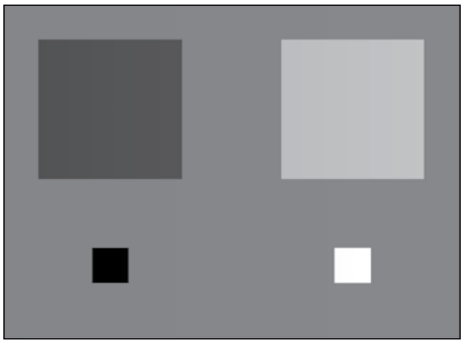
Why is high dynamic range a problem?

The answer lies in the limitations of the human visual system and in the limitations of typical video interfaces. A human observer can distinguish only approx. 128 levels of grey (7 bit) in an image. The challenge for each IR-camera is to map the information hidden in a 14 bit signal (>15000 levels of grey) to a 7bit signal a human observer can distinguish. In addition many analog and digital video interfaces require 8 bit values which effectively limits the dynamic range to 256 levels of grey, even if the end user is a not a human (e.g. target tracker).

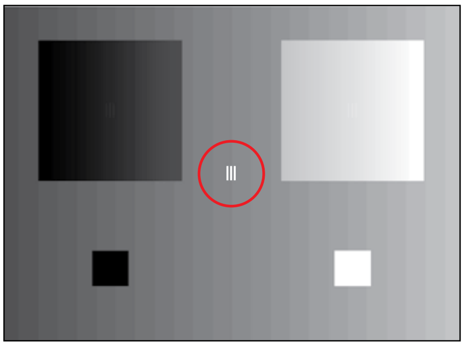
Isn't DDE just histogram equalization?

No. Histogram Equalization (HE) and the many variants of it work by the paradigm "More dynamic range (contrast) to the dominating temperature range and less dynamic range to image areas in the non dominating range." DDE on the other hand simply enhances all details equally, regardless of the temperature range that they happen to be in. This means a small hot object against a cold background will have as clear details as the background that happened to represent the dominating temperature range.

<u>Theoretical example:</u> Comparing linear AGC, HE & DDE using a theoretical five targets (ΔT≈200mK) image
In these 3 images, five sets of bar targets are hidden. Each target has approximately 200mK higher temperature than the background.

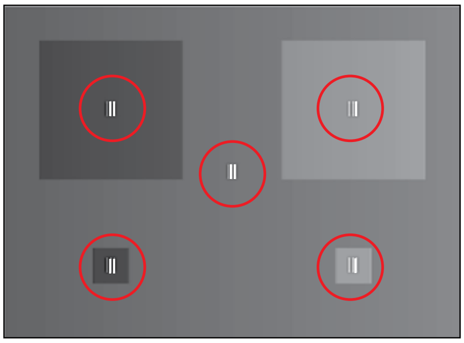


Picture 1: standard AGC – targets are hidden



Picture 2: HE – only one target will be visible

A standard AGC algorithm would not improve the image (Picture 1). The image shown in Picture 2 is enhanced using Histogram Equalization. As predicted, only the center target can be observed as it happens to be in the dominating dynamic range of this scene.



Picture 3: DDE – all targets become visible

Using FLIR Systems DDE algorithm (Picture 3) all five targets can be observed simultaneously. Also all five targets have the same contrast regardless of how many pixels happen to be in that particular part of the dynamic range. This is what makes DDE effective and predictable regardless of how the scene changes.

Traditional AGC algorithms remove extreme values and linearly map dynamic range onto 8bit domain. This will help very little in high dynamic range video. Histogram Equalization increases contrast in the dominating temperature/irradiance range. What if target is not in that dominating range? DDE gives a predefined portion of available contrast to details. The probability of detection of low contrast objects is constant over the image.

A real life example: How do we find low contrast targets in a high dynamic range image?

This video sequence shown in Picture 4 to 7 shows a scene with fairly high contrast. Gain* and Level** have been adjusted manually in Picture 5 & 6 in order to point out special low contrast targets.

Picture 4: high contrast scene with standard AGC algorithm applied

Picture 4 shows the video signal after a standard AGC algorithm has been applied. This algorithm will truncate the signal omitting the extreme pixels which gives more contrast to center part of the histogram. A moving target can easily be observed.

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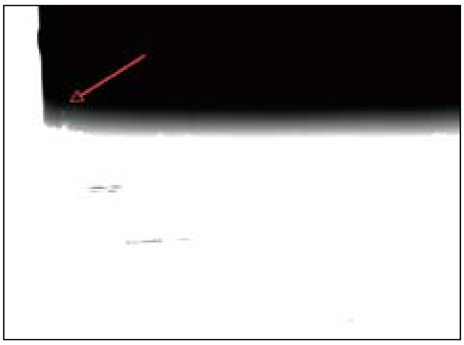
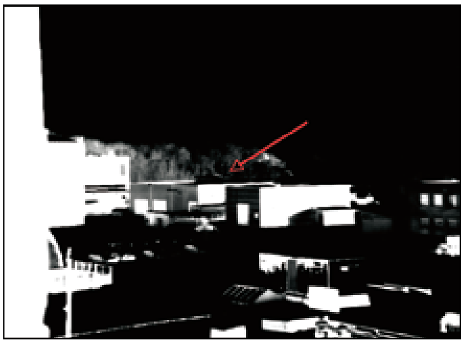


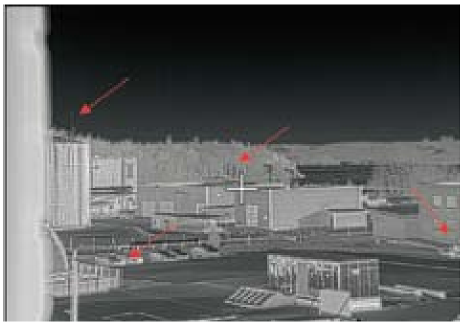
Picture 5: low end of the signal span allowing detection of a helicopter

Picture 5 shows the low end of the signal span and we can now detect a helicopter hovering in upper left corner of the image. This could be the potential target. Note that the helicopter is not visible on Picture 4.



Picture 6: narrow span in the middle of the dynamic range pointing out pixel sized targets in the woodlands – humans?

Picture 6 now shows a narrow span in the middle of the dynamic range. We can now see pixel sized targets in the woodlands across the straight of water. What if these people were actually the targets?



Picture 7: DDE applied - all targets can be observed simultaneously

Finally, Picture 7 shows the sequence filtered using FLIR's DDE algorithm. Now all three targets can be observed simultaneously. As can be seen there are very few artifacts in the image.

** The Level setting adjusts the center temperature of the display range. LEVEL controls the mid point scene temperature setting that will be viewed on a display. A low level setting results in cold scene temperatures being displayed in varying gray scale while any hot temperatures in the scene are all at full scale (i.e. white in white hot). A high level setting results in hot temperatures being shown in gray scale, with any cold temperatures being displayed as black (again in white hot).*

*** The Gain setting adjusts how wide a range of temperature will be mapped into the gray scale of the video display. Gain controls the range of scene temperatures that may be displayed by the camera and can be adjusted from Low to High. A low gain setting results in a wide temperature span (high dynamic range) being displayed but very small variations in scene temperature cannot be distinguished (low resolution). A high gain setting enables very small differences in scene temperature to be displayed (high resolution), but only over a smaller range of temperatures.*

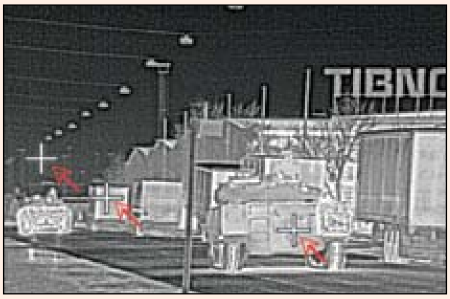
Real life example 2

Most Security & Surveillance applications require fast detection of targets without the need of the operator having to make manual adjustments. Minimizing the time to detect a target means displaying all possible targets simultaneously – even the low contrast targets - without the need of manually having to adjust gain and level.

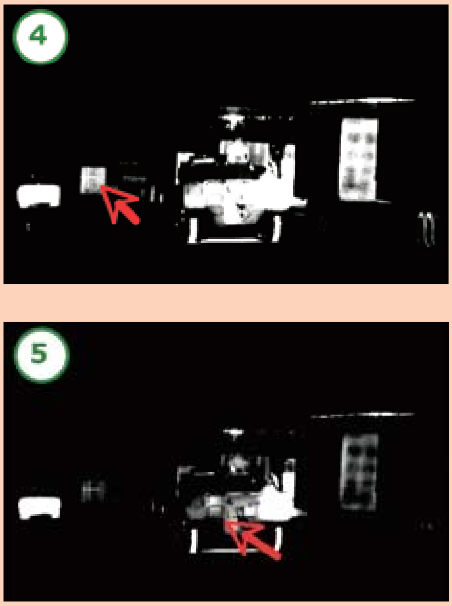
Picture 8: linear AGC – try to find five low contrast crosshairs within the image

The video sequence shown in Picture 8 has been captured using a high resolution 640 x 480 pixel detector and shows a high contrast scenery. Gain* and Level** have been adjusted manually in Picture 9 in order to point out special low contrast cross hairs. The camera is able to resolve the target but it can not be displayed to the user unless the user knows exactly within what part of the signal span the target is hidden. This will increase the time to detection significantly. Picture 10 shows the image to which DDE has been applied.

Unlike many other detail enhancement methods DDE is extremely robust to changing conditions. In practice, using DDE, the camera will produce near perfect video under every condition and the user can concentrate on the image and not the controls.



Picture 10: DDE – high & low contrast targets can be observed simultaneously



Picture 9: linear AGC – adjusting gain & level manually to point out the low contrast cross hairs

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