INFINITYX and DeltaVu™

“A Revolution in Resolution”

Technical Whitepaper
www.lumenera.com
DeltaVu™, a patent-pending methodology, represents a breakthrough in sub-pixel shifting technology resulting in increased image resolution and precise color. In theory, the only practical limitation on the resolving power of digital cameras using DeltaVu™ technology is the limitation of the optics being used.

The first product featuring this pioneering technology is the INFINITY™X high resolution USB microscope camera manufactured by Lumenera Corporation in Ottawa, Canada. The INFINITY™X achieves 32 megapixel resolution through shifting the 1616 x 1216 pixel array of a 1/1.8" color sensor. Users have the flexibility of choosing between 2, 8, 16, and 32-million pixel resolution taking full advantage of their research microscope optics to capture precise detail. Utilizing this technology also ensures that all three primary colors (Red, Green & Blue) are represented in each pixel for precise color reproduction.

Traditional Pixel Shifting Technology

Traditional pixel shifting technology enhances resolution by moving the image sensor typically half of a pixel between each image capture, sampling the object at more locations and simply using these extra captured pixels directly as image data. The increase in resolution of this technique is limited to the point where the active area of a given pixel begins to overlap with the pixel in the previous position. As the active area increases, the object starts to become over sampled and moving the sensor captures no new spatial information. Improvements in sensor technology have resulted in the active area of a pixel increasing to the point where it covers almost the entire pixel. With this higher "fill factor", the net gain in resolution information of traditional pixel shifting technology results is limited.

Most color digital cameras use a color filter array with a different primary color filter associated with each active pixel (e.g. Bayer mosaic). These cameras can take advantage of the traditional technology to help eliminate the artifacts associated with demosaicing the color array as a result of the required color interpolation. This is achieved by moving the pixels in whole pixel steps to capture images where every pixel location on the object is captured by pixels having each of the different color filters. Typically 4 images and 4 movements of the sensor are required to capture these images. The result is an image with every primary color captured by each pixel. Digital cameras using this method are often described as providing "true color" or "real color", because all pixels contain captured color information with no color interpolation being required.

The DeltaVu™ Difference

The INFINITY™X camera technology takes advantage of the increased fill factor in newer generation image sensors resulting in exact color representation in every pixel when compared to older pixel shifting technology. This is achieved through the INFINITY™X’s ability to capture and interpret details, which are much smaller than the size of a single pixel, dramatically increasing both spatial resolution and color quality.

The INFINITY™X shifts the sensor a fraction of a pixel between each image capture. The result is a large amount of overlap between neighboring pixels for each image captured. Knowing the precise location of each sub-pixel shift and using patent-pending software algorithms, images containing astonishing detail and enhanced color clarity are achieved. With this technique, objects much smaller than the size of an individual pixel can be resolved with no interpolation artifacts. In theory, by adjusting the amount of pixel overlap, the resolving power can be increased without limit. In practice, however, the resolution is restricted by the resolving power of the optical system.
This section provides a simplified illustration of how Lumenera’s **INFINITYX** camera’s unique DeltaVu™ image processing technology is implemented and how it differs from traditional methods.

**Traditional method of capturing and combining multiple images**

In the figure below, the 4 x 4 matrix represents the digital camera’s image sensor with high fill factor pixels. The Object is a black dot, 25% of the size of one of the image sensor’s pixels, against a white background. All required optics, illumination, etc. have been omitted for the sake of clarity.

The matrix below (labeled Pixels) is a flat view representation of the same 4 x 4 cells of the digital camera.

The 1st image is captured with the sensor in position 1. The 2nd image is captured after moving the sensor to the left by 50% of a pixel, to position 2. The 3rd image is captured after moving the sensor up by 50% of a pixel, to position 3. Finally, the 4th image is captured after moving the sensor to the right by 50% of a pixel to position 4.

Because the black dot is only 25% of the size of the pixel detecting it, the pixel will see it as a light gray color, a mixture of 25% black and 75% white.

Combining the 4 images captured with traditional technology will result in an oversampled image with 4 times the number of pixels. However, it will not contain more spatial detail. The first image captured already contained as much resolution as the final combined image, because the object is much smaller than the size of a pixel. However, as previously mentioned, for color cameras, this method does have the ability to improve the color quality.

**INFINITYX method of combining multiple images**

The **INFINITYX** makes use of DeltaVu™ technology to interpret and combine the information from multiple images as illustrated below.

The image captured in position 2 is placed on top of the image captured in position 1 and then shifted half a pixel to the left. Then, imagining that the pixels have some transparency, the result is a darker area (pixel), where the gray pixels overlap each other.

A similar process is repeated for the images captured in positions 3 and 4 where one image is placed on top of the other and shifted half a pixel. This will also result in a combined image with one darker pixel, where the 2 gray pixels overlap each other.

Next, the two combined images are placed on top of each other and shifted down by half a pixel. The combination of all 4 images will have one black pixel, where the 4 gray pixels in the 4 original images captured overlap each other, 4 dark gray pixels, where only 2 gray pixels from the original images overlap each other and 4 light gray pixels, where no pixels overlap from the original images.

In this case with 4 movements, the final **INFINITYX** image results in a single black pixel being isolated with a resolution 4 times higher than the number of active pixels in the sensor, and the digital camera can capture details down to 25% of the size of a pixel.

The resolution can be significantly increased through additional sub-pixel movements of the sensor until the limitation of the resolving power of the optics are reached.

In order to move the sensor quickly and very reliably, DeltaVu™ has implemented a newly developed electromechanical solution. Unlike the common piezo technology for moving the sensor, the new electromechanical solution is not sensitive to temperature, humidity, or aging and is free from internal friction.

The result is a compact digital camera with outstanding reliability and calibration free operation.