A new foundation for 1-D barcode reading

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The linear barcode reading market is currently dominated by opto-mechanical laser scanners. Image-based barcode readers offer potential advantages including no moving parts, improved yields on poorly printed or damaged codes, the ability to save images of misread objects, and the ability to read 2-D symbologies. But image-based barcode readers have been limited up to now by the poor fidelity and low speed of the image analysis methods used to find barcodes and extract 1D signals for decoding. Recently, novel image analysis methods have been developed that offer higher fidelity and very high speed of operation, allowing image-based readers to finally achieve their promised advantages.

Figure 1a. Barcode at 1.5 PPM, with projection line

Figure 2a. Barcode at 1.2 PPM, with projection line

In order to provide high geometric accuracy, good noise reduction and acceptable resolution, contemporary 1D signal extraction methods effectively rotate the image containing the barcode so that the projection line used to extract its signal becomes horizontal. Bilinear interpolation has up to now been the preferred method because it achieves an acceptable balance of geometric accuracy, resolution, noise reduction and speed. Figure 1a shows a barcode imaged at a resolution of 1.5 pixels per module or PPM (a module is the smallest bar or space) and a projection line (red) along which a 1-D signal is to be extracted for a decode attempt. Figure 1b shows the 1-D signal that results from use of bilinear interpolation. All of the bars and spaces present in the 2-D image have been faithfully reproduced, and a successful decode is assured.

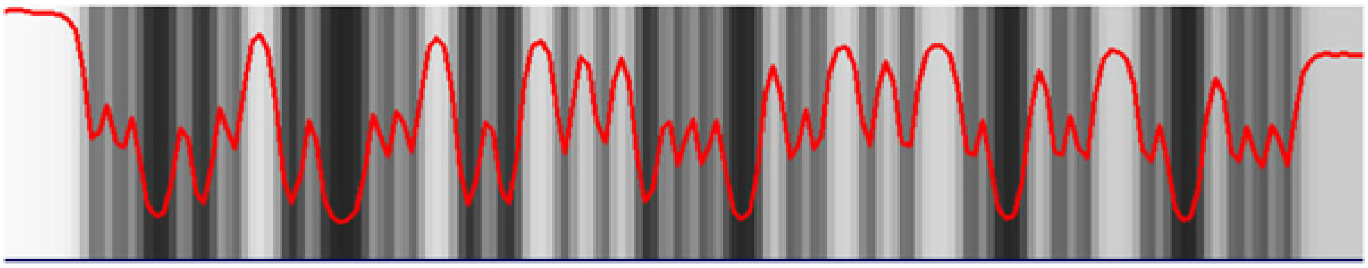

Figure 1b. 1-D signal extracted from 1.5 PPM barcode using bilinear interpolation

Figure 2a shows the same barcode, but imaged at a resolution of 1.2 PPM. This lower resolution allows for a wider field of view to be captured, but as can be seen in Figure 2b, the 1-D signal resulting from bilinear interpolation cannot resolve many of the finer features. Six bars and spaces, shown with blue circles, are severely attenuated, and three, shown with yellow circles, are completely lost. The 1-D signal at 1.2 PPM cannot be decoded using bilinear interpolation. But is there sufficient information in the image to allow for the extraction of a high fidelity 1-D signal by any means?

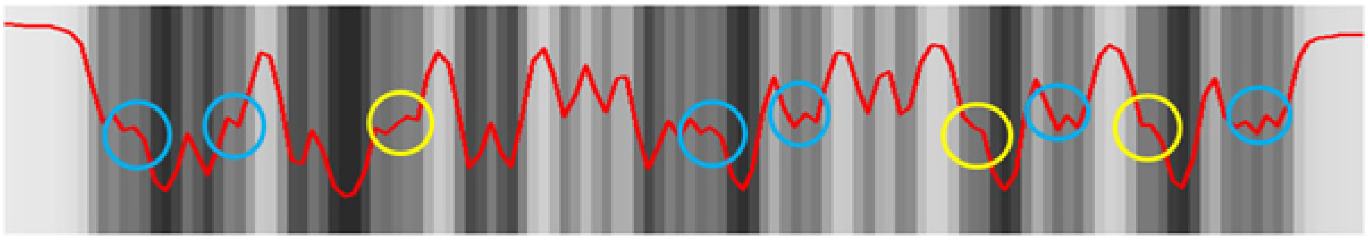

Figure 2b. 1-D signal extracted from 1.2 PPM barcode using bilinear interpolation, showing severely attenuated features in blue and completely lost features in yellow

Figure 3 shows a 1-D signal extracted from the same 1.2 PPM image, along the same projection line, but using the new Hotbars analysis method instead of bilinear interpolation. As can be seen, there are no severely attenuated or lost features, and so the signal can be decoded. The new method has the same essentially perfect geometric accuracy as any interpolation method, and achieves good noise reduction, but it introduces substantially less blur.

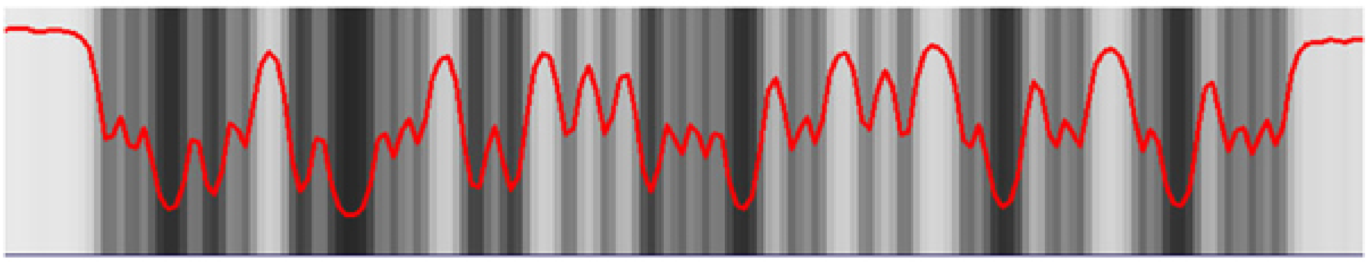

Figure 3. 1-D signal extracted from 1.2 PPM barcode using Hotbars, showing no loss of features

Interpolation methods are based on a model of rotation in the continuous plane, but a discrete pixel grid cannot accurately represent rotation at the small scales characteristic of fine features, and the result is some blurring of the signal. The new method has as its mathematical foundation a model of the behavior of the pixel grid itself, which allows blur to be reduced while maintaining perfect accuracy and good noise reduction. The spectacular difference between Figures 2b and 3 is due entirely to the method used for processing the source image.

Generally, sophisticated analysis comes at a price, and in machine vision that price is almost always speed. For the above examples, running on a relatively inexpensive DSP, bilinear interpolation requires around 200 µs to extract the signal. For the new method, the time is approximately 10 µs, about 20 times faster! The new method’s enormous signal extraction speed comes from using a novel and extremely efficient algorithm that is well-matched to contemporary DSP architecture. The novelty and efficiency are found in both the computation itself and in the way that memory is accessed, making the new approach to signal extraction much faster than even the simplest prior methods.

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