Real-time Multi Barcode Reader for Industrial Applications

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ABSTRACT

The advances in automated production processes have resulted in the need for detecting, reading and decoding 2D datamatrix barcodes at very high speeds. This requires the correct combination of high speed optical devices that are capable of capturing high quality images and computer vision algorithms that can read and decode the barcodes accurately. Such barcode readers should also be capable of resolving fundamental imaging challenges arising from blurred barcode edges, reflections from possible polyethylene wrapping, poor and/or non-uniform illumination, fluctuations of focus, rotation and scale changes. Addressing the above challenges in this paper we propose the design and implementation of a high speed multi-barcode reader and provide test results from an industrial trial. To authors knowledge such a comprehensive system has not been proposed and fully investigated in existing literature. To reduce the reflections on the images caused due to polyethylene wrapping used in typical packaging, polarising filters have been used. The images captured using the optical system above will still include imperfections and variations due to scale, rotation, illumination etc. We use a number of novel image enhancement algorithms optimised for use with 2D datamatrix barcodes for image de-blurring, contrast point and self-shadow removal using an affine transform based approach and non-uniform illumination correction. The enhanced images are subsequently used for barcode detection and recognition. We provide experimental results from a factory trial of using the multi-barcode reader and evaluate the performance of each optical unit and computer vision algorithm used. The results indicate an overall accuracy of 99.6 % in barcode recognition at typical speeds of industrial conveyor systems.

Keywords: Two-Dimensional Barcodes, Barcode Detection/decoding, Datamatrix

1. INTRODUCTION

2D barcodes such as Datamatrix [1] are being used extensively in several industries such as automotive, aerospace, consumer goods, electronics, semiconductor, and life sciences. Detecting and decoding 2D barcodes under normal conditions is not a complex problem. However, the problem arises when the captured images are of poor quality due to reflections and self-shadows produced due to the possible presence of product wrapping in the form of polyester foiling. Poor lighting conditions also affect the detection.

Previous work in this area focuses only on the development of image processing algorithms to improve the detection and decoding of 2D barcodes under poor environmental conditions. N.Normand and C. Viard-Gaudin [2] proposed a method for bar code localization and reading. The localization of symbol is carried out by the extraction of high density area of mono-oriented gradients. The reading method is based on detection of transitions between the stripes by extracting the zero-crossings of the second derivative of the 1D signal reconstructed from the 2D barcode block. E.Ouaviani et al[3]. proposed a simple image processing approach suitable to locate, segment and decode the most common 2D symbols in real time images. The Image is represented in terms of magnitude and phase of the gradient. Finally the ROI is computed by grouping the connected blocks which share the same directional characteristics. Code location is performed by a standard edge detection and linking approach in which edge points are grouped in chains. Decoding has been done by taking the segmented area and meshed, resampled and binarized in order to compute the bit pattern of the code. The method works well with images with bad illumination conditions and with strong perspective deformation. Y Liang, et al [4] proposed a method which includes three steps: The first step detects the code region using the Otsu algorithm [5] and the Least Square Method (LSM). The second method searches for the cut-off rules with a scanning approach. In the third

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step symbol characters are segmented from the original image. Experimental results show the accuracy and performance of this method are acceptable, especially the capability of dealing with noisy images. However, for deformed images, the method is computationally expensive. Julie [6] proposed a method which includes adaptive thresholding, region labeling and property calculation, candidate region determination and marker detection. This technique has limitation in detecting bar codes with varying aspect ratio and rotation. In methodology [7] 2D barcode reading for PDF417 symbology have been proposed. Barcode's geometric features and the imaging system parameters are jointly extracted from a tilted low resolution image. This approach enables the use of cost effective cameras, enhances the depth of acquisition and provides solution for low resolution images.

Most of the techniques discussed in literature, work for single 2D barcode detection and decoding. The barcodes are not wrapped in any reflective material such as polyethylene foiling. The proposed work however, not only uses image processing techniques but also proposes an optical hardware setup to address the issues related to decoding of 2D barcodes under reflection and poor illumination conditions.

Apart from this section which provided an insight to the problem domain and information on existing state-of-the art solutions, section 2 provides an overview to the concepts used in proposed work. Section 3 presents the proposed methodology. Section 4 provides experimental results and a detailed analysis. Finally section 5 concludes with an insight to possible future improvements to the methodology proposed in this paper.

2. BACKGROUND

This section discusses the theory behind the concepts used in the proposed work.

2.1 Datamatrix

Datamatrix (see figure 1 (a)) is a 2D symbology that features a rectangular or square array of dark and white modules used to encode data. The symbol has a *finder pattern*, which is used to locate and orient the symbol. This pattern consists of a vertical and horizontal bar that is one module wide on the left and bottom sides of the symbol as shown in figure 1(centre) and alternate set of dark and light modules on the right and top sides. Alternate dark bright cells are used for code size information as shown in Figure 1 (right).[1]

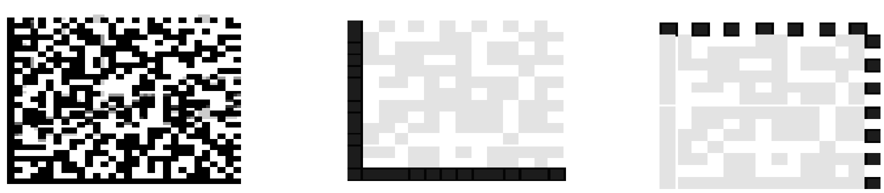

Figure1.Left to right Datamatrix Symbol, Finder Pattern, Alternate dark and light modules[1]

2.2 CogPMAlign Tool Cognex VisionPro5.2

In VisionPro5.2, the CogPMAlign tool uses Cognex PatMax software to perform pattern location. A PatMax pattern is a collection of geometric features and the spatial relationship between them, where each feature is a collection of points on the boundary between two regions of dissimilar pixel values. Like other pattern-location technologies, PatMax trains a pattern and then locates one or more instances of that pattern in one or more run-time images. PatMax training results in a pattern that contains geometric features. PatMax differs from other pattern-location technologies in that it is not based on pixel grid representations that cannot be efficiently and accurately rotated or scaled. Instead, PatMax uses a feature-based representation that can be transformed quickly and accurately for pattern matching. PatMax can find objects whose appearance varies in size (overall size change or individual x- and y-axis size change), rotation and location.

2.3 Cog 2DSymbol Tool Cognex VisionPro5.2

The 2D Symbol tool decodes 2D Data Matrix symbols and Quick Response (QR) Code symbols. The tool needs to be trained before it can be used. Training a 2D Symbol tool establishes the values of parameters that the tool needs in order to successfully decode symbols repeatedly, such as the size of the symbol grid, the particular symbology (Data Matrix or QR Code) and the error checking and correction (ECC) method the symbol uses to verify the accuracy of the data it contains.ECC level allows data recovery despite an increasing amount of damaged or unreadable symbol area. As the application executes it decodes each new symbol and makes the encoded string available to other vision tools or to the user.

3. PROPOSED WORK

The proposed method is a combination of optical hardware setup and the software solution.

3.1 Optical set-up

To handle the issues related to the reflections, self shadows and poor illumination problems, an optical setup consisting of Red LED backlights, Linear polarising filters and dark red band-pass filters is proposed as depicted in block diagram Figure 2 (top) and actual setup installed at factory as shown in Figure 2(bottom).

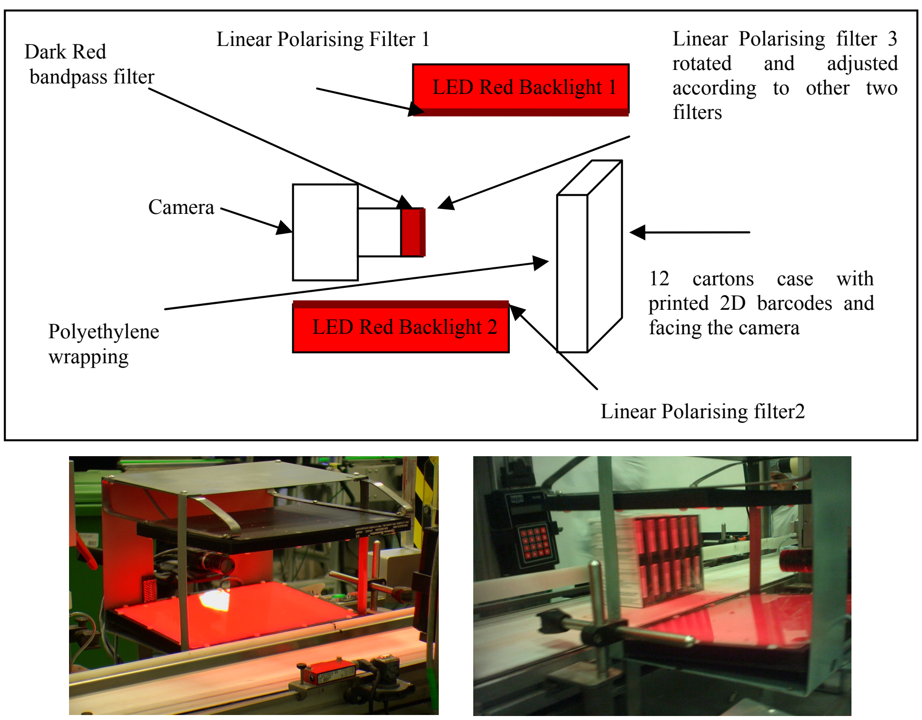

Figure 2. Top: Block diagram of proposed setup, Bottom: Optical hardware setup as installed at the factory

Use of an LED light source provides advantages over traditional light sources including, the possibility of strobing these, long operating life and stable light outputs over their life span. In the proposed system we use two 12”x8” LED 660nm red backlights with a built in Strobe and powered 24VDC by a power supply as shown in Figure 2. Secondly, the use of the band-pass filters means that only the light from the light source enters the camera and any external light is massively reduced. It greatly improves the contrast and depth of field as opposed to using white light or no band-pass filter (due to different wavelengths of light being focused in a slightly different place by standard lenses). In the proposed system we have used dark red bandpass-660nm filters which only allow light from the red backlights to enter the camera. Lastly to remove the reflections on the images caused due to polyethylene foiling, polarising filters have been used. This allows removing much of the unwanted reflections caused by the polyethylene film. This is achieved because the axis of polarized light emitted from the lights is altered when it is reflected, hence when the camera polarized filter is set at the correct angle relative to the light source polarized filter, any light that is out of phase (reflections) can be removed. The effect of using the proposed optical setup on the captured images of 2D barcodes is explained in Section 4. Once images are captured with multiple 2D barcodes, these are processed using Cognex VisionPro5.2 software. The stepwise procedure of detection and decoding of 2D barcodes is shown with help of a flow chart in Figure 3 and can be explained as follows:

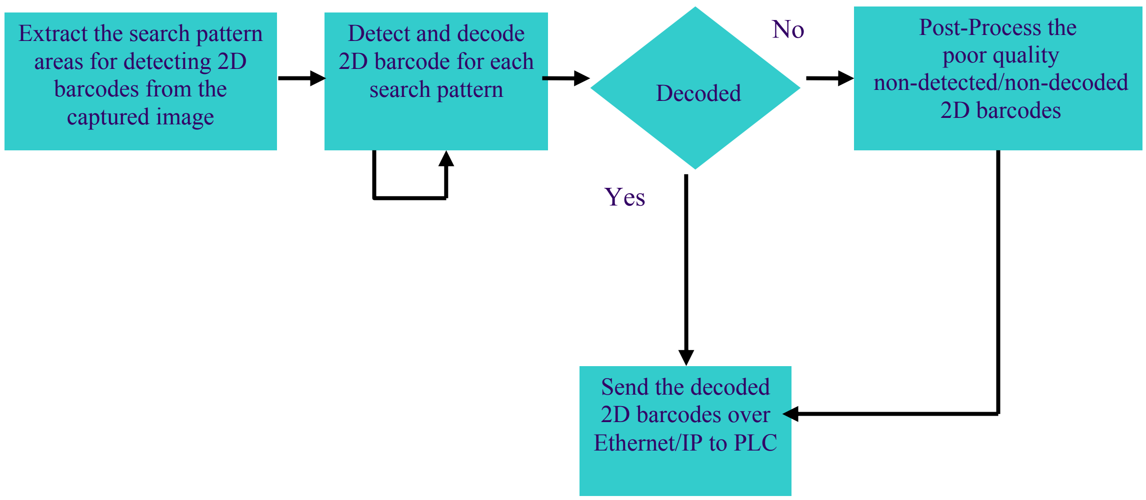

Figure 3. Multiple 2D Barcode Reader

Stage1: Since the captured image contains multiple 2D barcodes and each barcode is located on a white rectangular region, it is appropriate to first locate these white rectangular patterns. CogPMAlign Tool within Cognex VisionPro5.2 is therefore first trained and applied to the captured image to find these patterns as shown in Figure 4.

Stage2: Taking each white pattern as the search region, a 2D barcode is detected and decoded within this area using Cog2DSymbol tool of Cognex VisionPro 5.2.

Stage3: After applying the 2D barcode detector, the results are stored to check which one of the barcodes are detected/decoded and which ones are not.

Stage4: The barcodes which are not decoded properly are further processed to improve the quality by using standard approaches to de-blurring, contrast enhancement, non-uniform illumination correction etc. Further an previously proposed by us for shadow removal has been modified to enable highlight removal and has been utilized to minimise any remaining effects of reflections (see section 3.2).

Stage5: The decoded data is then transferred to the PLC.

3.2 Software Processing

A number of standard approaches for image enhancement have been used to further remove the effects of image imperfections.

Image De-bluring: Bluring of datametrix patterns can lead to the reduction of resolution that can lead to non-detection of barcode due to the confidence level of barcode reading to be below a reasonable figure. We have adopted the standard

MATLAB de-bluring function ‘deconvblind’ that uses ap approach based on blind de-convolution and a maximum likelihood function.

Contrast Enhancement – The captured datamatrix images can be of low contrast due to a number of reasons. The idea of this enhancement stage is to improve contrast that will lead to an improved barcode read rate. We used the ‘imadjust’ function of the MATLAB image processing toolbox to achieve contrast enhancement. Out of several available MATLAB functions for contrast adjustment, this was experimentally found to be the best and appropriate for contrast enhancement of datamatrix images.

Non-Uniform Illumination Correction – When capturing images through polystyrene wrapping non-uniform illumination can lead to difficulties and inaccuracies of reading 2D barcodes. Some areas of the barcode may be illuminated at a different level than to another due to shadows, highlights and reflections. We have adopted the retrospective correction of non-uniform illumination approach proposed in [9] to correct non-uniform illuminations.

Highlight Removal – Highlights present in the barcode read areas and the immediate surroundings can cause non-detection and non-recognition of barcodes. To address this issue we have used a modified version of a shadow removal algorithm we have proposed in the past [10]. The modifications were required to change the affine modal parameters used in this work so that it is able to handle highlights, which can be considered as affecting in a contrastingly different manner optically to that of shadows.

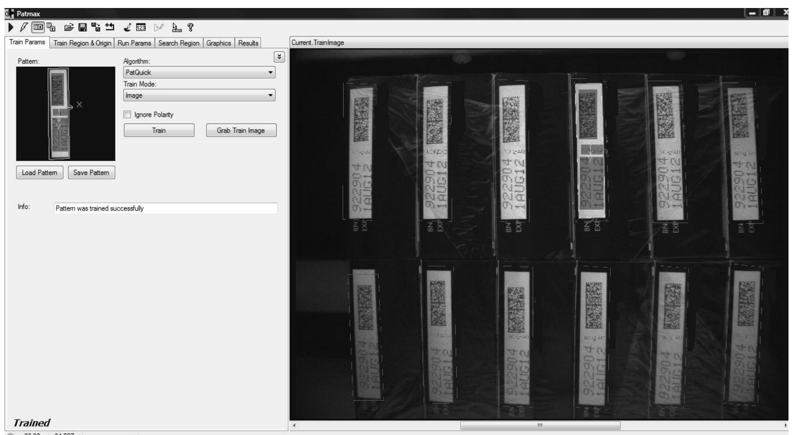

Figure 4. CogPMAlign Tool training phase on white rectangular Patterns

4. EXPERIMENTAL RESULTS AND ANALYSIS

The experiments were conducted on 100 sample images captured during a trail factory run of the system, where each image consisted of multiple barcodes under laboratory and factory conditions as shown in Figure 4 The images were captured for moving products using Point Grey Research Flea®2, model no. FL2-20S4M/C-C camera having Fujinon 1:1.4/9mm HF9HA-1B lens and 1624x1224 pixels resolution at 15 FPS frame rate. Following are the settings used for Image Source tool in Cognex VisionPro 5.2:

- Exposure → 2ms
- Brightness → 0.9
- Contrast → 0.7
- Distance of camera for complete field of view → 8 inch

The above parameters were experimentally found out to provide the optimum read results during out trails. However adjustments will be required to these values if the environmental and geometrical set up conditions are changed,

4.1 Experimental Results and Analysis - testing the proposed system under laboratory conditions

Experiment 1: Detection of barcodes, Image taken under normal lighting conditions (fluorescent, partially diffused)

Experiments were performed to analyse the performance of the proposed system under the following variations:

- Illumination variation
- reflections due to foil wrapping
- packing quality
- Print quality of barcodes

Figure 5 illustrates the effects of polyethylene foiling to the general captured image quality of a single barcode. It is observed that as long as the foil has been wrapped tight (e.g. vacuum wrapped) the quality of the foiled barcode is comparable to the quality of un-foiled barcode. We assume that the above assumption is reasonable.

Figure 6 illustrates the effects of foiling, in particular reflections, effects due to end folds and packing quality. Note that in figure 6(left) the reflections are due to overlapped lose foil. Reflections can also be present when having a single layer of foil due to the direction and nature of lighting source. For example a point light source can cause bright reflections onto the camera lens. Figure 6(right) illustrates how the end folds of the foil can make the image distorted. Careful analysis of this image revealed that the problem with the end fold is not the edge, but the reflections caused by the looseness of foil and overlapping.

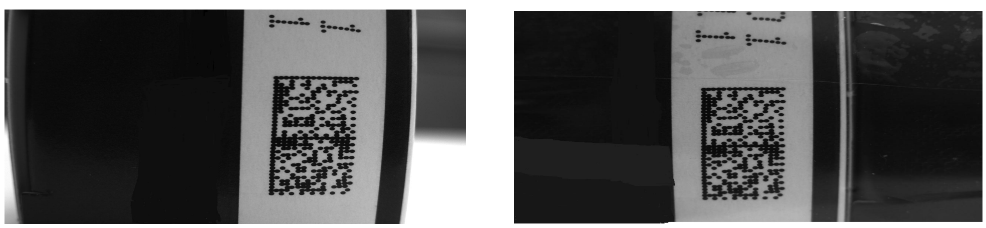

Figure 5. Effects of tight foiling: left – Non-foiled, right– Foiled

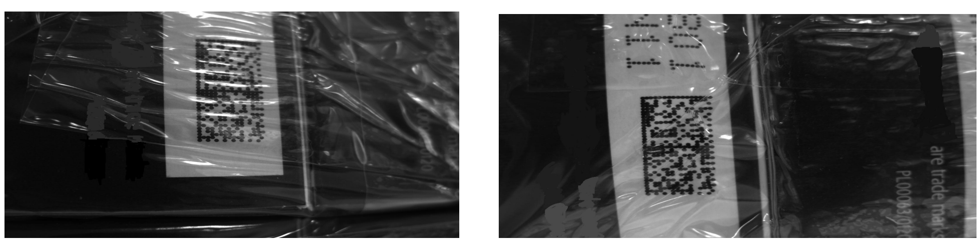

Figure 6. Effects due to foiling: left- Reflections   right- End folds

Figure 7 illustrates the effects of poor print quality in the barcode decoding capability of the Cognex VisionPro. It is observed that when the white background is not present around the barcode and the print has been smudged, the barcodes are not decoded.

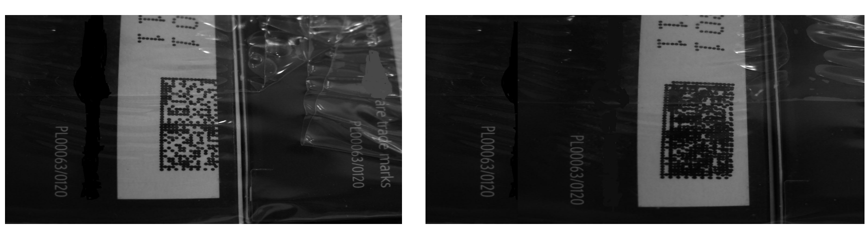

Figure 7. Non-decoded barcodes: Left – white background on one side is not present, Right – the print has been smudged.

The experimental results obtained after applying the proposed multiple 2D barcode reader is shown in Figure 8. (Note that the barcodes used in this example are not the complete barcodes).

The barcodes which are not decoded are the ones which have either reflection due to illumination, foiling, or wrongly printed.

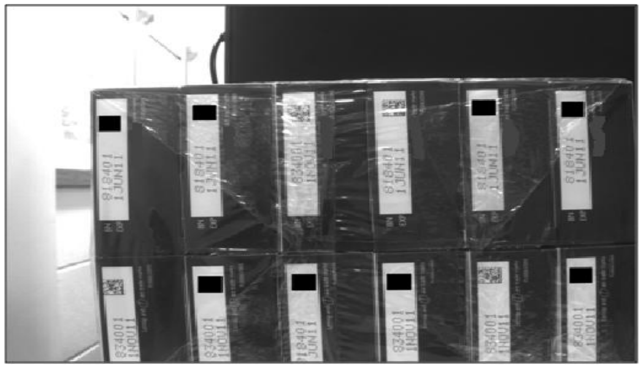

Figure 8. 2DBarcode Reader results on image under normal lighting conditions

Experiment 2: Detection of barcodes in Images obtained using the proposed setup (Red LED backlight and red bandpass Filter)

In order to improve the performance of 2D barcode reader and reduce the effects of unwanted light sources, an experiment was carried out with help of proposed setup. The only light which could fall on the image was the red light. A comparison between the images taken under normal lighting conditions (see Figure 9(a)) and by using the combination of red backlights and filter is shown in Figure 9(b).

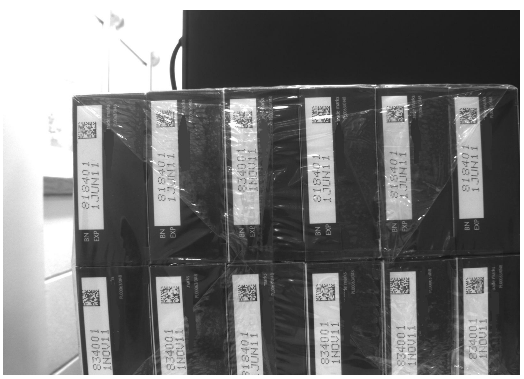

Figure 9(a). Image taken under normal lighting conditions (fluorescent, partially diffused)

Figure 9(b). Image taken using Red LED backlight and red bandpass Filter

The results of Figure9 (b) clearly show that the light from external resources has been greatly reduced and the quality of image has improved in contrast to that of Figure 9(a). However the image in Figure 9(b) still has reflections.

Experiment 3: Detection of barcodes in Images obtained using the proposed method (Red LED backlight and Red bandpass Filter along with Polarised filters)

This experiment was performed to check the effect of applying a polarised filter on reducing reflections. Figure 10 shows the results.

Figure 10. Use of polarising filter

The comparison between Figure 9(b) and Figure 10 proves that most of the reflections have been removed. Figure 11(a) and (b) show the results of applying the proposed Cognex VisionPro based multiple 2D barcode Reader on the proposed version2 setup. In Figure 11(a), only non-decoded barcode is the one which is wrongly printed. The marked rectangles around the barcodes in Figure 11(b) show that these barcodes have been detected and decoded successfully.

Figure 11(a). Two dimensional barcode reader results on improved image

Figure 11(b). Two dimensional barcode reader results

4.2 Experimental Results and Analysis using proposed system (Factory Trials)

The proposed optical setup and the barcode reader software were tested during the factory trials. An average read of 10.98 barcodes from cases of 12 barcodes was obtained when tested on 100 cases. A further investigation revealed that the barcodes that are not read were the ones located furthest from the camera axis. The reason was that these barcodes were not sufficiently lit.

5. CONCLUSION

In this paper, we have proposed a system comprising optical hardware and image processing algorithms to detect and decode 2D barcodes symbology (Datamatrix) in Real Time. The proposed system is capable of reading barcodes under rotation, illumination variation, distortion, motion blur and reflections. We have experimented this setup in an industrial environment and found out that the system has an accuracy figure of approximately 98%. In cases where the barcodes are not read they are also not detected. Hence this minimises the false positive rate.

6. ACKNOWLEDGMENT

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