Using colour cameras for digital image correlation: how bad are they?

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Introduction

Digital Image Correlation (DIC) is used to measure full-field displacement values using images from a digital camera of a speckle pattern that is fixed to, and deforms with the surface of a sample. Results from DIC are sensitive to the camera employed. High quality, very high-resolution colour cameras are available relatively inexpensively and so is there a point at which this increase in resolution allows them to outperform monochrome cameras in strain resolution?

In most cases, colour cameras use a colour filter array (CFA) in a Bayer pattern [1] to permit the capture measurement of values for each of the red (R), green (G) and blue (B) colour channels. Using cameras with a CFA for DIC is widely accepted as inferior to a monochrome device. When a feature moves from one pixel to a neighbouring pixel it causes an identical or near identical response in the image is a primary assumption for using DIC. With a CFA applied, this assumption is broken. Each photosite has a colour filter applied to it that makes it only sensitive to a narrower band of frequencies (Figure 1). This means that the measured intensity of the feature as it moves across the sensor will vary dependent on its colour and which filter is applied to a particular photosite.

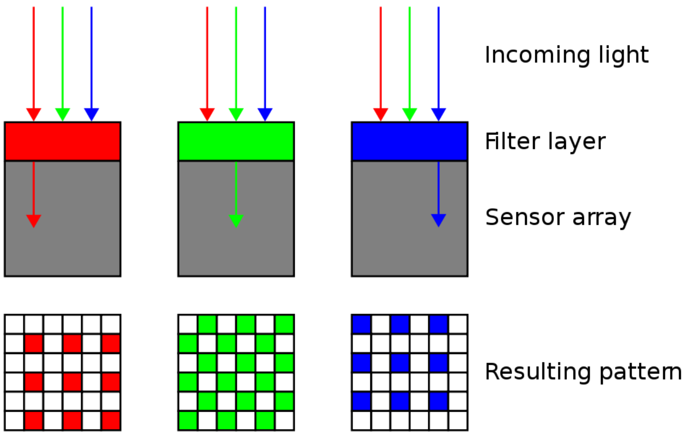

Figure 1: Schematic of a Bayer colour filter array (image source: WikiCommons)

Demosaicing is the process of turning the data captured by a camera with a CFA, one value for either the R, G or B channel, into an image with RGB values at every pixel position. To enable the colour camera to perform as well as possible, a number of commercial demosaicing algorithms were tested, along with our own variants on standard demosaicing approaches. The vast majority of the demosaicing literature is concerned with production of a pleasing image, not optimisation for measurement techniques [2,3,4].

Methodology

The difference between demosaicing algorithms was measured in two ways. The first was to use a rigid body displacement to produce a uniform displacement field. The second was to use images of a speckle pattern on a rotation stage, mounted so that the speckle pattern can be rotated in the plane of the image. This rotation gives a well-constrained displacement field, but allows non-zero values in the antisymmetric part of the strain tensor. The value of this part of the strain tensor is therefore known to be non-zero and uniform across the entire image, regardless of the rotation applied. Similarly the symmetric part of the strain tensor is known to be zero throughout the image. Any measured deviation from this is error and is pseudo-strain produced by the measurement process.

The cameras used for the comparison were a Nikon D810 consumer camera and a Nikon DS-Qi2 scientific camera using the same Nikon 200mm f4 micro lens. The DIC was analysed using LaVision's DaVis 8's least squares analysis at a number of sub-region sizes.

Results

The lowest pseudo strain was seen in the linear and Gaussian demosaicing methods as can be seen in Figure 2. The Gaussian difference method was inferior to these two, and as this algorithm is used primarily for colour preservation this is may not be surprising. The two commercial programs, Corel Photo Paint and Nikon View NX2 were by far the worst performers.

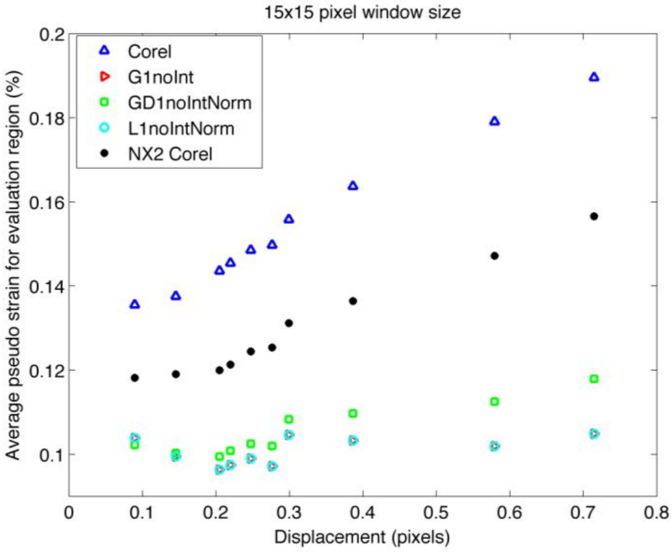

Figure 2: Pseudo-strain produced at different pixel fractions for five different demosaicing algorithms used on the same set of images.

Discussion

Demosaicing algorithms that use a local approach to interpolating images from a camera with a CFA produce significantly lower error than commercial methods. This is because the commercial methods have been developed to solve a different problem, to produce a pleasing image. However, no demosaicing method on a camera with a CFA can compete with a monochrome camera on a direct pixel-to-pixel basis. The benefit that the CFA cameras have is the sheer number of pixels, 36.6 megapixels in the case of the D810 in comparison to 16 megapixels for the monochrome DS-Qi2. This allows the D810 to use a larger number of pixels to be used for a given area on a sample surface, at a given magnification. The downside of this is that it does inevitably lead to a requirement for more computation time. This is both due to the larger number of pixels for each image, but also the requirement of the extra demosaicing step before DIC can be performed. It is hoped that this study will spur more interest in addressing this problem in the future.

References

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