

Demosaicing images from colour cameras for digital image correlation



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ABSTRACT

Digital image correlation is not the intended use for consumer colour cameras, but with care they can be successfully employed in such a role. The main obstacle is the sparsely sampled colour data caused by the use of a colour filter array (CFA) to separate the colour channels. It is shown that the method used to convert consumer camera raw files into a monochrome image suitable for digital image correlation (DIC) can have a significant effect on the DIC output. A number of widely available software packages and two in-house methods are evaluated in terms of their performance when used with DIC. Using an in-plane rotating disc to produce a highly constrained displacement field, it was found that the bicubic spline based in-house demosaicing method outperformed the other methods in terms of accuracy and aliasing suppression.

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1. Introduction

Digital Image Correlation (DIC) [1,2] is an increasingly popular technique for measuring spatially resolved surface strain. Its principle is based on computational tracking of contrasting surface features on digital images. One of the main attractions is the relatively simple equipment required and that is simply a device capable of taking suitable images, most often a camera. Typically, two or more images are acquired before and after a loading event and the relative movements of the surface features in each image are determined. High measurement accuracy relies on resolving features at a sub-pixel level. This is best achieved when the light intensity of each pixel is registered accurately, as in the case of monochrome cameras. It is possible to use colour cameras for DIC, but first the colour information must be converted into a monochrome signal and the method by which this is achieved can have a significant effect on the eventual result. Therefore, scientific monochrome cameras are predominantly used for DIC so that this processing step can be removed and because on a pixel-to-pixel comparison the colour cameras are at a disadvantage. There has been a large body of work dedicated to the measurement or estimation of error in DIC. This work generally considers the error caused by different algorithms [3], different parts of the algorithm [4,5], or methods for estimating error [6]. To the authors' knowledge there are no published studies on the effects of using colour camera for DIC other than Yoneyama [7], who use a 3 CCD colour camera rather than one with a colour filter array (CFA). This arrangement removes the problem of sparse sampling of each colour

channel, but does not represent the configuration of the majority of digital colour cameras. For cameras using CFAs, only statements in papers that have used colour cameras that allude to their effects [8] have been found.

There are situations where using a colour camera could have an advantage, but this is mainly down to grounds of cost. Due to the large market demand for colour cameras, high quality models can be obtained for a fraction of the cost of dedicated scientific cameras. These consumer cameras have a faster product life cycle and can possess a large pixel count. These cameras are not designed to take scientific measurements and so they have multiple undesirable features not found on scientific cameras. These are specifically, and not limited to, CFAs, pixel lenses, anti-aliasing filters, and a viewfinder mirror mechanism. However, for long term testing where a camera is in place for months [9,10], the cheaper colour cameras may still be an attractive proposition. With the additional resolution of these cameras, there are other situations in which they may be preferable to the monochrome scientific cameras, such as crack detection. There also must be a comparable resolution at which a good quality colour camera will gain performance parity with a monochrome camera of a lower resolution, due to the higher resolution colour camera being able to use more pixels in each subregion to obtain the same spatial resolution.

2. Demosaicing

When performing DIC, a monochrome camera is preferable over a colour camera of the same resolution, unless the colour information is required for a separate purpose. These cameras are made up of photosites that all have similar sensitivity and so any

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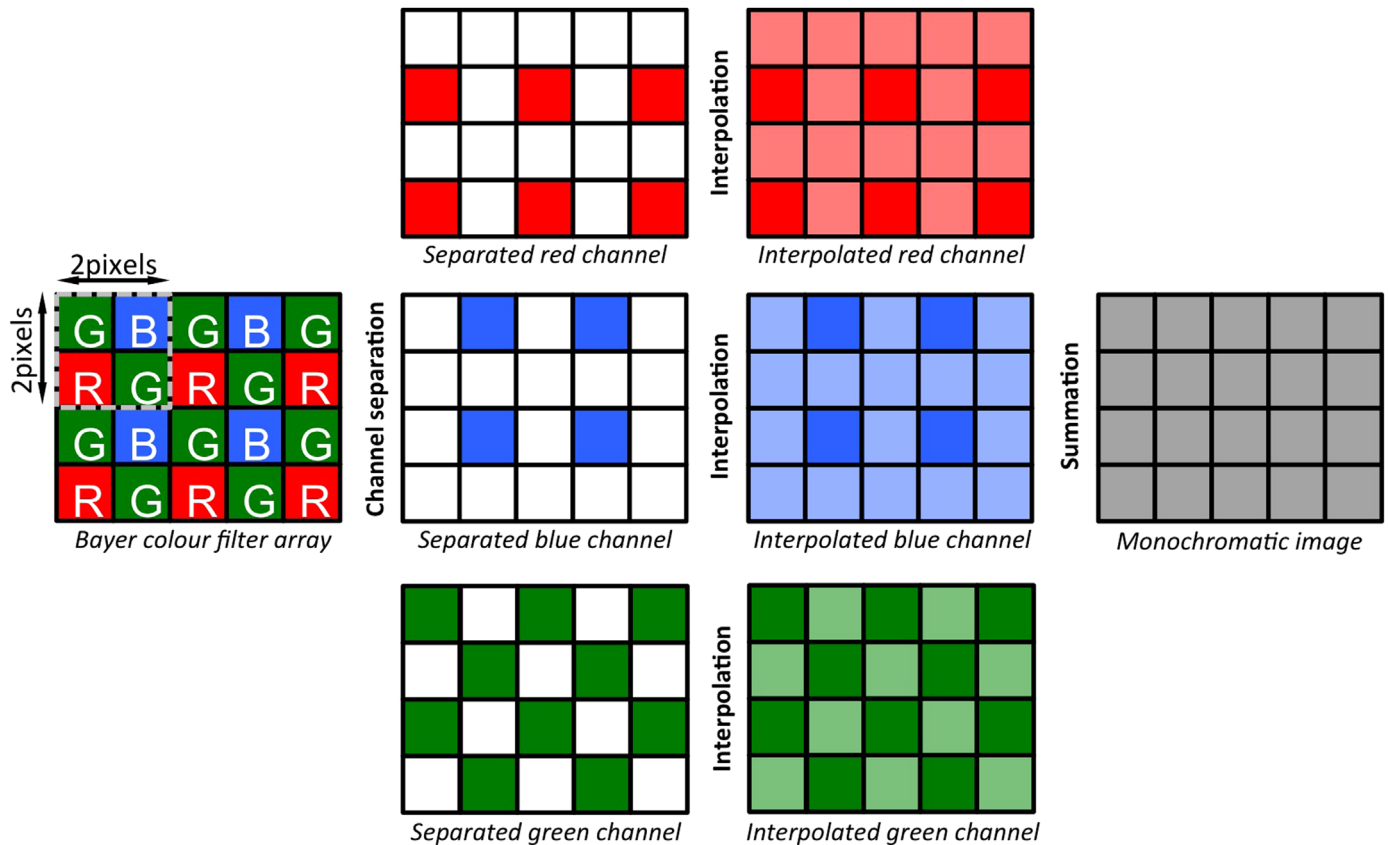


Fig. 1. Schematic of Bayer colour filter array (with the 2×2 pixel repeating unit highlighted with dashed outline) showing how it is used in the in-house bilinear and bicubic spline demosaicing methods. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

speckle moving from one pixel to the next will produce a similar and predictable response. The majority of colour cameras use a CFA to make individual pixels sensitive to red, green or blue (some cameras separate to CMYK, but the principle remains the same). The arrangement of the CFA of the colour camera described in this paper is a Bayer pattern [11]. This pattern has twice the number of green photosites as red or blue arranged in a 2×2 pixel repeating-unit, as seen in Fig. 1. From this sparse colour sampling, a full colour image is produced by interpolating the unknown values in each colour channel. This interpolation is achieved via any one of the many demosaicing algorithms available [12–14] to calculate a red, green and blue value for every pixel position, where only data from one channel was captured. These three channels, red, green and blue, can then be combined to create a monochrome image suitable for DIC.

The requirements for the demosaicing process to perform successful DIC using a colour camera are somewhat different to that of that to create a successful photograph. A monochrome output from the camera is required and the result should be as repeatable as possible when the sample is subjected to sub-pixel shifts. The first condition is simple to achieve, the second is much more problematic due to the sparse sampling of each colour channel. One of the aims of this study is to investigate the effect of how the colour channels are combined to produce a monochrome image for DIC and the resulting output.

For consumer cameras, the raw mosaic image can be accessed though saving images in the proprietary raw format. Many algorithms are available for producing a full colour image from these sparsely sampled colour channels caused by the CFA. For DIC, a monochrome image is required as the correlation is performed on a single regular array of data. This is so that the speckle pattern, specifically the difference in light intensity between contrasting

features, moves from one pixel to the next as displacement increases. The aim of the demosaicing conversion is to allow a DIC algorithm to make the best use of the available data from the three colour channels. Two in-house methods will be tested here, bilinear interpolation and bicubic spline interpolation. These two are then benchmarked against a typical commercial package, in this case Corel Photo Paint [15]. Five other algorithms from the open source RAWtherapee software are then considered and all algorithms used are summarised in Table 1. The aim of this is not to promote or condemn the Corel software or an open source approach, merely to provide context for the other methods presented. Corel Photo Paint was chosen because of its ability to produce a suitable *tif* file that can be read by the LaVision software (16 bit, monochrome, uncompressed *tif*) in a single programme and as such would be a convenient choice for any user. The conversion using Corel Photo Paint was performed using software's default settings of sharpness and colour balance. RAWtherapee was chosen due to its range of demosaicing algorithms from a single open source. In this case the images were converted to

Table 1
Summary of demosaicing algorithms considered in this investigation.

Demosaicing method	Comment	Refs.
Ahd	Adaptive homogeneity directed	[16]
AMaZE	Aliasing Minimisation and Zipper Elimination	[17]
Bicubic	Bicubic spline interpolation	In-house
Corel PP X4	Proprietary software	[15]
dcb	Gózdź method	[18]
eahd	Horváth's AHD	[19]
Linear	Bilinear polynomial interpolation	In-house
vng4	Variable Number of Gradients	[20]

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