

Original Research Paper

Image Processing of Friction Stir Welded 6060-T5 Aluminum Alloy Joint

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Abstract: Image processing can be a breakthrough in aerospace and manufacturing industries. In this research study, Friction Stir Welding of 6060 T5 Alloy is carried out. The image obtained of the Friction Stir Welded joint is subjected to basic image processing techniques using the OpenCV computer vision library and some standard data analysis libraries in Python.

Keywords: Friction Stir Welding, Computer Vision, Image Processing, Machine Learning

Introduction

Image Processing is a machine learning technique which is basically used to perform various operations on an image, in order to get an enhanced image or to extract some useful image features from it (Russ, 1990; Lim, 1990; Abramoff *et al.*, 2004; Pavlidis, 2012). Image Processing has been used by various industries for detection of surface defects. Elbehiery *et al.* (2005) used an image processing method for the detection of surface defects in ceramic tiles. Vasilic and Hocenski (2006) used the edge detecting image processing method for ceramic tiles defects detection on the basis of color and surface texture. García-Alegre *et al.* (2000) carried out study on the eggshell defect detection by using color processing method. Liu *et al.* (2007) used a rapid real-time defect detection image processing algorithm based on the pixels brightness for defects detection on rail tracks.

In the present work, image processing is used to extract various features like generating histograms from color and grayscale image, histogram equalization and generating Fourier transform of the grayscale image of the friction stir welded joint. Friction Stir Welding process is a novel solid state joining technique developed by The Welding Institute in 1991. Friction Stir Welding process overcomes the drawbacks of various conventional welding process (Mishra and Ma, 2005; Thomas and Nicholas, 1997; Guerra *et al.*, 2002). Friction Stir Welding is generally used to join aluminum alloys, magnesium alloys and as well as various titanium alloys which find application in aerospace industries (Threadgill *et al.*, 2009; Kwon, 2008; Dressler *et al.*, 2009; Mishra and Dixit, 2018). In this case study, AA 6060-T5 alloy is used for Friction Stir Welding purpose.

Materials and Methods

Aluminum alloy plate 6060 T5 of the dimension 150×100×6 mm was joined by Friction Stir Welding process. The plate was fixed on the fixture mounted on the CNC bed and tool fabricated from H13 steel is used for joining the plates. The input parameters which should be properly monitored in Friction Stir Welding process for obtaining sound joints are Tool Rotational Speed (rpm), Tool Traverse Speed (mm/min) and Axial Force.



Fig 1: Cropped image of friction stir welded joint

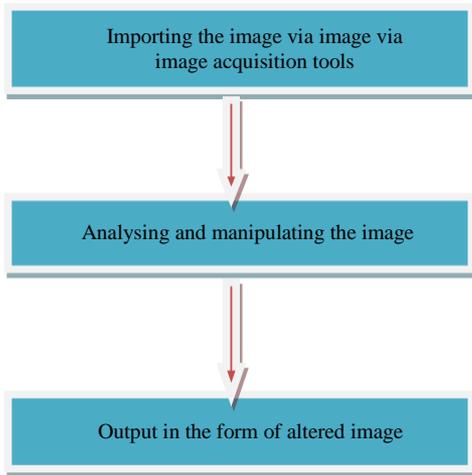


Fig. 2: Image processing steps carried out via friction stir welded image

In this case study Tool Rotational Speed of 1500 rpm, Tool Traverse speed of 400 mm/min and an axial force of 2.5KN were used. With the help of a digital camera, image of the welded joint was captured and further cropping process is done to the size of 814×2559 pixels for the image processing task as shown in the Fig. 1.

Jupyter notebook using Python 3.0 programming language on the Google Colaboratory platform is used for developing image processing algorithm while using opencv, numpy and matplotlib libraries. Image processing method is implemented in three steps as shown in the Fig. 2.

Results and Discussion

In the first step image is read from urls and display it by using openCV, please note the difference when reading image in RGB and BGR format. The default input color channels are in BGR format for openCV. The obtained result is shown in the Fig. 3.

Sometimes it is desired to enhance the contrast in a particular image or expand the contrast in a particular region while sacrificing the detail in colors that don't vary much, or don't matter. A good tool to find interesting regions is the histogram shown in the Fig. 4. To create a histogram of our image data, we use the matplotlib.pyplot.hist() function.

Figure 6 represents the grayscale image. Histogram of the grayscale image is shown in the Fig. 7. It is observed that the frequency of the image histogram has decreased ~ 1/3 of the histogram of color image.

Figure 8 shows the obtained contour by using matplotlib.pyplot.contour.

Grayscale transformation and histogram equalization was performed on the given image. Grayscale transformation is an inverse operation of the grayscale image, it is seen from Fig. 9 that the bright pixels become dark and the dark pixels become bright.

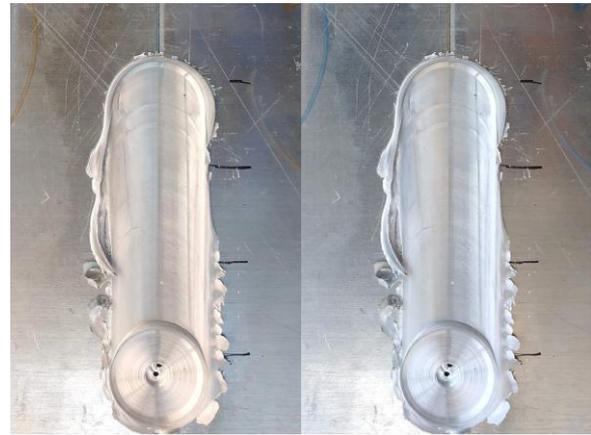


Fig. 3: Read and display

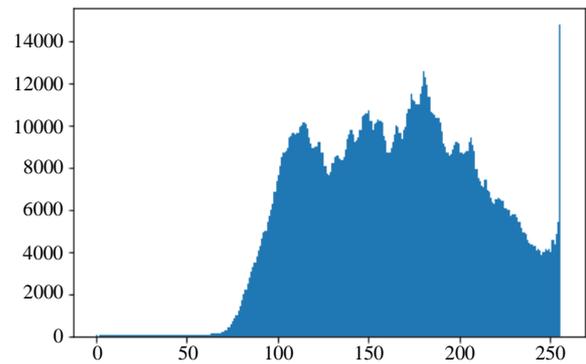


Fig. 4: Histogram of all the pixels in the color image

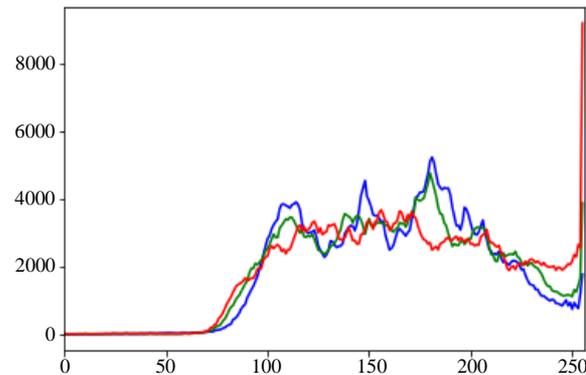


Fig. 5: Histogram of R, G, B channel

Figure 5 display the histogram of R, G, B channel. It is observed that the green channel has many pixels in 255, which represents the white patch in the image.

Another transform of the image shown in the Fig. 10, after adding a constant, all the pixels become brighter and a hazing-like effect of the image is generated.

Histogram Equalization transform flattens the gray-level histogram so that all intensities are as equally

common as possible which is compared in Fig. 11 and 12. The transform function is a cumulative distribution function (cdf) of the pixel values in the image (normalized to map the range of pixel values to the desired range).



Fig. 6: Grayscale image

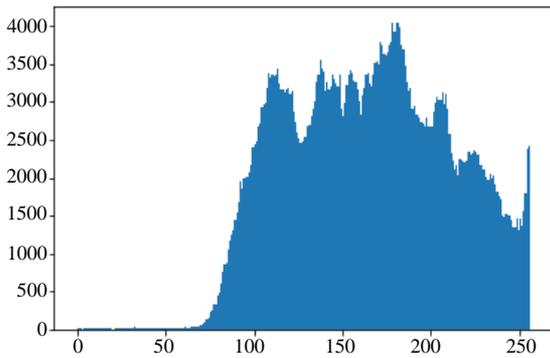


Fig. 7: Histogram of the grayscale image

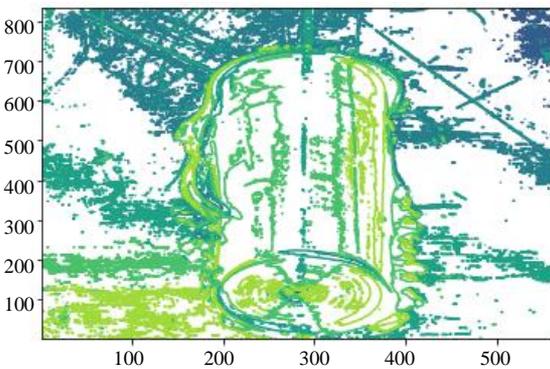


Fig. 8: Contour of the friction stir welded joint image

A Fourier transform is used to find the frequency domain of an image. You can consider an image as a signal which is sampled in two directions as shown in the Fig. 13. So taking a Fourier transformation in both X and Y direction gives you the frequency representation of image. For the sinusoidal signal, if the amplitude varies so fast in short time, you can say it is a high frequency signal. If it varies slowly, it is a low frequency signal. Edges and noises are high frequency contents in an image because they change drastically in images.



Fig. 9: Grayscale transformation of the image



Fig. 10: Haze effect in image

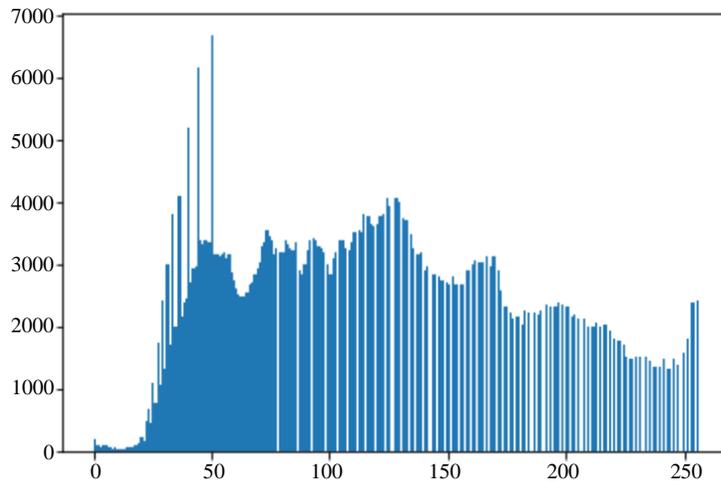


Fig. 11: Before histogram equalization

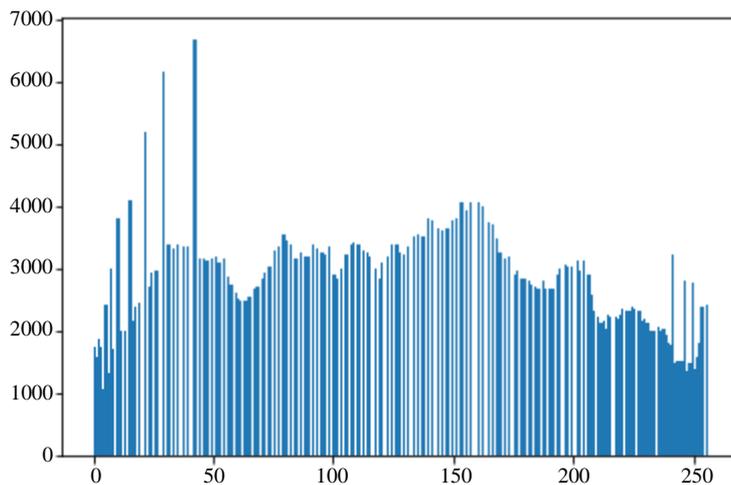


Fig. 12: After histogram equalization

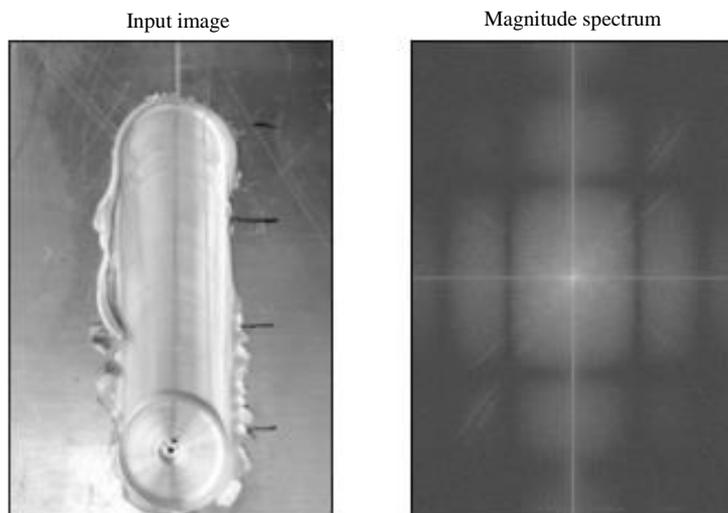


Fig. 13: Fourier transform of the grayscale image

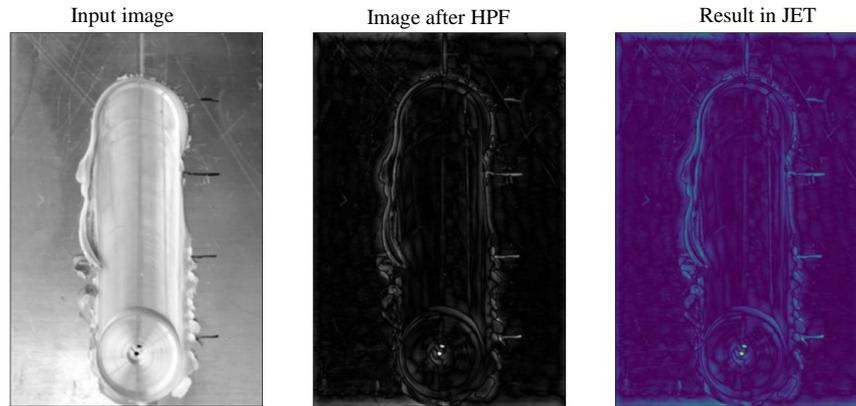


Fig. 14: Conduction of high pass filter

Figure 14 demonstrates conducting a high pass filter to remove the low frequency component, resulting in a sharpened image which contains the edges.

Conclusion

Image processing is successfully implemented on the image of Friction Stir Welded joint for extracting the necessary features from the image. Improper selection of the input parameters like Tool Rotational Speed, tool traverse speed and axial force during friction stir welding process may result in flash formation, groovy edges formation and other various types of surface defects. So, image processing techniques used in this research work can be also used for the detection of any types of irregularities or surface defects present on the Friction Stir Welded joint. Hence, it can be used as an application for monitoring of the quality of the welded joints.

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Ethics

This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and no ethical issues involved.

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