

A Performance Analysis of Different Scanning Paths on Lossless Image Compression for Radiographic Welding Images

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Image compression plays a major role in saving bandwidth and memory space which is the need of hour. In industry various components are tested effectively using NDT (Non-Destructive Testing) and this information is stored in the system. To reduce the memory space required for storing, lossless compression is used. This paper focuses on the various scanning paths methods for lossless compression like spiral, cross, raster, snake, peano and zigzag. These methods are compared on the basis of activity measure, average run length and sum of differences and the result of each method is sent to the Run Length Encoding (RLE) and Huffman for compression. Four different methods are used for compression of the images. In the first method, the binary value of the image is taken directly for compression. In the second method, the binary values are converted into corresponding gray values, before compression. In the third method, the binary bit plane is taken for compression. In the fourth method, the gray code bit plane is taken for compression. The above obtained results are compared with the results from calculation of efficiency parameters. Out of the different scanning methods, spiral and peano performed better than the other methods. Thus, the optimal scanning path for welding radiographic images was identified thereby reducing the bandwidth and can be used for lossless compression which achieves more compression ratio.

Keywords: Image compression, Run Length Encoding, Huffman, Gray code, Scan path

Introduction

Image processing plays a major role in areas like medicine, machine vision and pattern recognition. Each bit of information in an image is required in future for performing operations like classification, retrieval, recognition etc. Image compression is required to save bandwidth and memory space. Compression is to reduce the size from the original image or text. Based on the decompressed data obtained from the compressed image, it may be divided into lossless or lossy compression. Some applications require an exact replica of the original image rather than a compressed ratio⁵. Data compression methods can be either reversible (error-free) or irreversible (lossy)¹⁻³. Normally, 2.5 is the utmost ratio of compression a reversible strategy can provide, but the original image can be easily recovered. Noise and other degrading factors which are present in the image generally bound the typical pixel correlation⁴. Different methods of lossless compression techniques include run-length encoding, entropy encoding, chain codes etc. An irreversible

scheme will not allow exact recovery. After the process of compression, this scheme does not provide us with the luxury of the original image retrieval, but can easily accomplish a larger ratio of compression. But image quality is the one that is needed to be compromised. The compression ratio for an irreversible technique can be as high as 2.5 for projectional chest radiographs without noticeable loss of image quality³. Different methods of lossy compression techniques include transform coding, fractal compression etc. Moreover the lossy and lossless compressions can be classified based on transform methods and predictive methods⁵. However, a method of compression may fall into more than one category based on different classifications. This paper discusses about lossless image compression using different scan paths for welded radiographic images. The results are compared and an optimized compression technique is found.

Destructive testing provides a dependable assessment of the state of the test object, destruction of the test object itself makes this type of test more expensive to the test object's owner than the typical Non Destructive Testing. Destructive testing is also

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unfitting in many contexts, such as in forensic investigation. Since there is a trade-off between the cost of the test and its reliability, we typically see the need for test objects to be tested non-destructively¹³.

Materials and methods

This paper compares different ways of scanning like raster horizontal, raster vertical, snake horizontal, snake vertical, spiral, cross, zigzag etc and its performance. Scanning of an image is visiting each element in the image exactly once⁶. Scanning is used to determine the order of visiting the element in the image for compression. The aim of scanning is to move the spatial redundancy as much as possible. Raster scanning method traverses the pixel either in the horizontal or vertical direction. Raster horizontal and raster vertical scanning methods might not give expected results because of the uncorrelated pixel values at the end of one line with that of the start of the next line. To avoid this problem and to preserve the correlation, the snake horizontal and snake vertical method is proposed⁷. Nonlinear scanning is better for real images because the values of the pixels are non-homogeneous⁶.

Some measures to determine the better scanning path which gives more compression was proposed by Nandakishore⁷. The parameters are activity measure, average run length measure and sum of difference measure. Activity measure shows the number of transitions in the scan. If the number of transitions is low then the redundancy of the pixel intensity value is more. Average run length is a statistical analysis of the occurrences of each length. It calculates the ratio of number of occurrence of a particular length of repeating pattern to the length of the sequence. This value should be more because the continuous value of the pixel values pattern is to be high. The sum of differences should be low because this shows the relativeness between current pixel values with neighboring pixels. Based on this parameter the better scanning path is identified and this path gives better compression rates than the other scanning methods.

An adaptive coding technique used in block based image compression schemes⁸. Edge presence and edge orientation measures are then calculated using discrete cosine transform coefficients. Hou *et al.*⁹ proposed a concept of all phase bi-orthogonal transform based on discrete cosine transform. This transform technique is then used for image compression instead of conventional discrete cosine

transform. This method has the advantage of simplified quantization table, less computing time and easy hardware implementation.

Douak *et al.*¹⁰ developed a lossy image compression algorithm which can be used for color still images. Adaptive scanning is done followed by a systematic encoder for achieving compression. A low bit rate image compression technique for transmitting image data via underwater channel which has limited bandwidth¹¹. Krinidis *et al.*¹² have introduced a discrete modal transform which is a generalization of discrete cosine transform. It is a non-separable transform for signal processing which can be used for image compression.

An x-ray testing method is typically aggregated with algorithms of processing of digital images by the digital radiography. Rapid development in this field has led to the introduction of fresh NDT methods¹⁴. The non-destructive methods (e.g. X-ray, ultrasonic and magnetic methods) measure some parameters that are related to the judgment of component-inspected damage, without taking out the material¹⁵. NDT methods assess the integrity of an aircraft structure to improve reliability and availability of an aircraft¹⁶. NDT techniques render fitting inspection and evaluation means that can be used to administer the compliance of airworthiness for civil aircraft structures¹⁷. Non Destructive Testing is used to analyze the interior property of a structural object including its material property and physical alignment of the particles inside an object without damaging the object under consideration¹⁸.

Results and discussion

In this experiment different radiographic welding images are taken and tested with an algorithm. The algorithm is implemented using MATLAB and Java. The image which has to be compressed is taken and different scanning paths are applied viz., spiral, cross, peano 1, peano 2, peano 3, raster horizontal, raster vertical, snake horizontal, snake vertical, z horizontal, z vertical and zigzag. The files generated by applying these scanning paths are then used to calculate path efficiency parameters such as Activity Measure (AM), Average Run Length measure (ARL) and Sum of Difference measure (SD) for each path. The four different compression cases which will be discussed below are applied on these files. The scanning path which provided the highest compression in each case is noted. Also, the paths which provided high efficiency in terms of AM, ARL and SD are noted.

In most cases, peano 3 scanning path provided maximum compression. Similarly the path that provided highest efficiency in terms of ARL measure parameter provided maximum compression. In most cases, the path which provided highest compression and the path suggested by ARL measure parameter are the same. Therefore it can be seen that the path which provides maximum compression and the path selected by ARL measure parameter have high correlation.

For the given image, the pixel value is generated and it can be read in different ways as mentioned above. For each scanning path its corresponding file will be generated. After getting the different scan path files, the best scanning path is identified. This has been cross checked with four different sequences of compression operation. The four cases are applied to the initially generated file scanning paths. This is shown in Fig 1.

In Case 1 which is depicted in Fig 2, each pixel value is converted into its binary. For this binary value RLE is applied. Simple RLE does not provide the expected compression ratio. So the Huffman technique is applied to the obtained RLE result. The advantage of Huffman code generation is that, it is a variable length code. It takes more number of bits to represent the least frequent values and less number of bits to represent the most frequent values. Case 3 is similar to Case 1, except the first stage. In Case 3, instead of taking the binary values of the pixel binary, bit plane is applied.

In Case 2, each pixel's gray code value is taken for the compression process. The gray code has the advantage of only one bit change with any of its neighboring pixel value. The gray code value is applied with RLE and Huffman. Case 4 is same as that of Case 2, except the inclusion of the gray code bit plane. For the decompression process, the whole sequence has to be reversed. By using the Huffman tree, the counts of ones and zero are obtained. Then this will be replaced by number of ones and zero. This

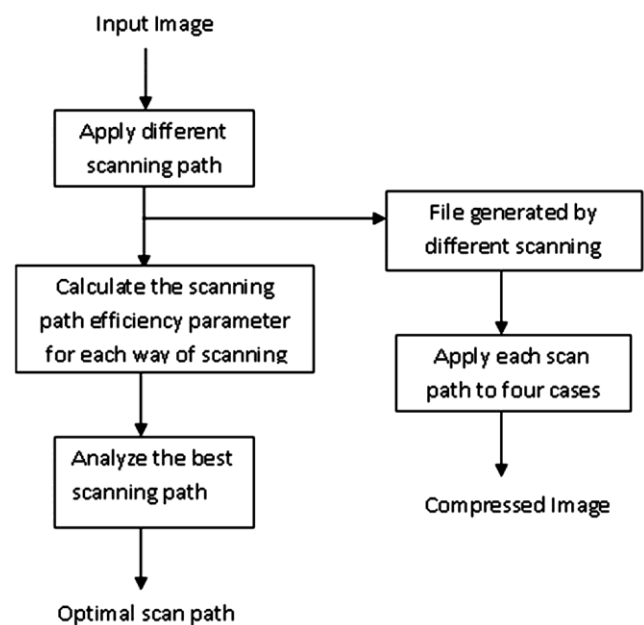


Fig. 1—Generating files using scan path and apply the compression

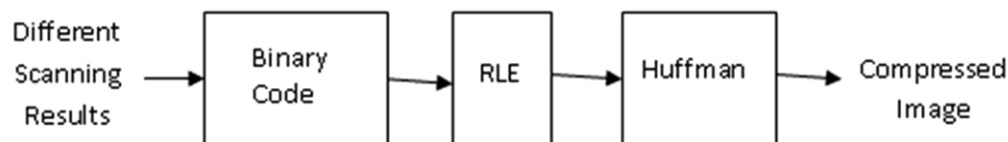


Fig. 2—Case 1: Binary value of the pixel applied to RLE and Huffman

Table 1—Compressed file size(MB) in different scanning path with four cases

		Spiral	Cross	Peano 1	Peano 2	Peano 3	RH	RV	SH	SV	ZH	ZV	ZZ
Actual Image1	Case 1	22.03	22.04	22.03	22.03	22.03	22.03	22.03	22.03	22.03	22.03	22.03	22.03
	Case 2	21.91	21.91	21.91	21.91	21.91	21.91	21.91	21.91	21.91	21.91	21.91	21.91
	Case 3	12.07	12.07	12.05	12.04	12.04	12.11	12.20	12.09	12.17	12.05	12.10	12.25
	Case 4	10.43	10.39	10.40	10.39	10.38	10.47	10.57	10.45	10.52	10.40	10.45	10.62
After Enhancement Image1	Case 1	22.48	22.50	22.49	22.49	22.49	22.49	22.49	22.49	22.49	22.49	22.49	22.49
	Case 2	22.66	22.67	22.66	22.66	22.66	22.66	22.67	22.66	22.66	22.66	22.67	22.67
	Case 3	17.63	17.65	17.62	17.61	17.60	17.68	17.77	17.66	17.72	17.62	17.66	17.81
	Case 4	16.94	16.90	16.91	16.89	16.89	16.99	17.08	16.97	17.03	16.91	16.96	17.15

Table 2—Scanning path efficiency results for Image1

Scan Type	Activity Measure	Average Run Length	Sum of Difference
Raster Horizontal	11735801	1.108965	316329710
Raster Vertical	11743322	1.121001	348629370
Snake Horizontal	11734950	1.118723	311720482
Snake Vertical	11741600	1.128421	334944948
Z Horizontal	11740638	1.115684	329843516
Z Vertical	11745181	1.123789	345960612
Zig Zag	11745729	1.109318	345028440
Spiral	11734638	1.130518	310388914
Cross	10776833	1.063501	324704795
Peano-Hilbert 1	11805044	1.041971	244831986
Peano-Hilbert 2	11756822	1.127354	303623725
peano-Hilbert 3	11744166	1.454077	318305498

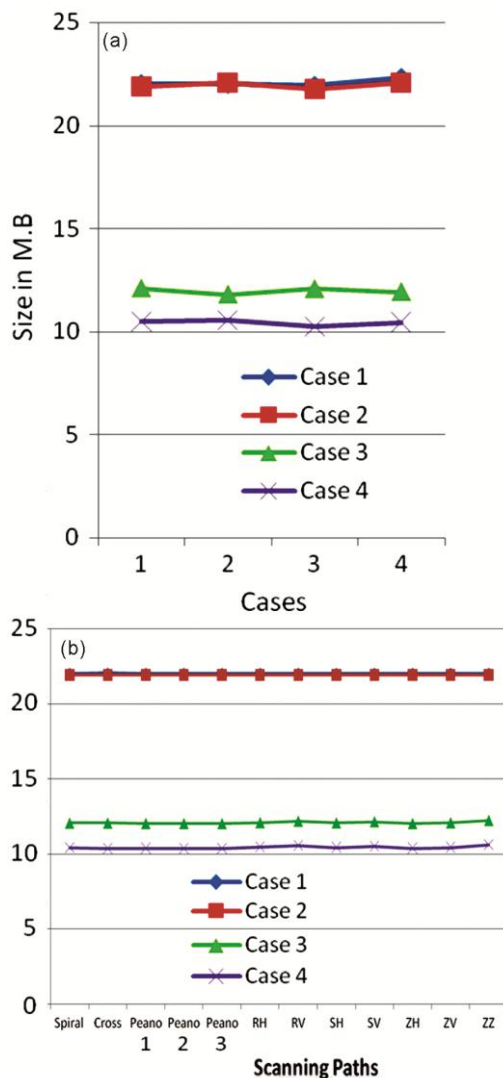


Fig. 3(a)—Comparison of four cases and memory space required;
 (b)—Comparison of different scanning paths and its memory space obtained

value is converted into pixel value with or without bit plane.

Conclusion

In this paper, the different scanning path results are compared using the path efficiency parameters. The original image and the enhanced image are applied with the same test cases. After applying the image enhancement, each pixel in the image will have more information which increases the compressed image's size as shown in Table 1. The best scanning path can be described as the one which could tightly pack similar pixels in an image. On comparing the results of compression obtained from the different scanning path methods and the path efficiency parameters, it is concluded from Table 2 that the scanning path which provides maximum compression and the path which has the highest efficiency with respect to activity run length measure parameter will have high correlation. Fig 3a depicts the comparison between four cases and memory space required which clearly shows that Case 4 is providing a better compression than the other three cases. Fig 3b shows the different scanning paths where the peano and spiral scanning paths are found to be performing the best in this regard.

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