New Approaches for Defect Recognition with X-ray Testing

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September 26, 2002

Abstract

New approaches for automatic defect recognition with X-ray testing were recently presented at the 8^{th} European Conference on Non-destructive Testing (ECNDT-2002, Barcelona). In this article these approaches are reviewed.

Keywords: X-ray testing, casting inspection, welding defects, image processing, automatic defect recognition.

1 Introduction

Six new approaches in X-ray testing were recently presented at the 8^{th} European Conference on Non-destructive Testing in Barcelona. The published methods use different strategies in order to perform an automated detection of defects. In the following Sections, the six methodologies will be briefly described. Some of them were developed for die cast pieces, while others are for welding seams.

2 Automatic Inspector

A new methodology based on neuronal networks for automatic defect recognition in aluminium castings was presented in [10]. The neuronal networks are used in two tasks: *a)* selection of regions of interest (ROI's), and *b)* configuration of detection filters. The ROI's are selected in order to inspect every part of the image with different settings. For each ROI a filter is configured. After an automated training phase, where no action of the operator is required, the filters are able to estimate a reference image from the test image. Defects are detected where the difference is considerable. More details of the algorithm are not given in the paper.

3 Block correlative approach

In reference methods it is necessary to take still images at selected programmed inspection positions. A test image is then compared with the reference image. If a significant difference is identified, the test piece is classified as defective. In order to use a *golden image*, i.e. a stored reference image, the distribution of grey values in the image must correlate to the test image. It is well known in defect recognition based on reference methods, that the use of a golden image makes a very precise positioning of the piece, as well as very strict fabrication tolerances, and the reproducibility of the X-ray parameters during imaging indispensable. Small variations in these variables lead to great differences between the two images [7]. A solution to this problem was recently suggested in [11], whereby a block correlative approach and confidence based filtering are used.

The block correlative approach is based on an optical flow methodology: the test image is divided into blocks, and for each block X of the test image a local translation vector is estimated by finding a block Y in the golden image where the correlation between X and Y is maximal. The resulting displacement field is regularised using a confidence index. Thus, the accuracy of the displacement of blocks containing few structures can be improved by including neighbouring blocks. The reference image is then warped into the geometry of the inspected one by translating each block according to the estimated displacement vectors. Once this procedure is done, the detection is performed by simple difference between corrected golden image and test image.

According to the authors, the new algorithm achieves a satisfactory detection rate on real X-ray images. However, the parameters of the method must be correctly tuned.

4 Trained median filter

A new methodology based on the signal synchronised filter [7] is presented for the automatic defect recognition in aluminium castings [3]. The *Trained Median Filter* (TMF) is a non-linear, non-local filter where the kernel consist of the whole X-ray image. In the filtering, the output pixel $y[i,j]$ is defined as the median of the input pixel $x[i,j]$ and three pixels that are similar to $x[i,j]$, i.e. $y[i,j] = \text{median}(x[i,j], R_1, R_2, R_3)$. In a training phase, the three similar pixels are selected for each pixel of the image. The idea is to find those pixels (in the whole image) that have a similar behaviour to $x[i,j]$ in representative piece images which were obtained from the same cast piece and same position without defects. Since the test images are flawless, the training is unsupervised in the sense that all regions obtained in the segmentation process belong to the class 'regular structure'. In this unsupervised training the TMF generates a knowledge database of flawless X-ray images of the cast piece. The obtained knowledge base is used in a classification process in order to distinguish between defects and regular structures automatically.

Both very small flaws defects with very low contrast and big low intensity defects with superposed structures can be detected. The computation time of this method is very low.

5 Defect recognition using shape features

A method for automated recognition of welding defects was presented in [8]. The detection follows a pattern recognition methodology: *a)* Segmentation: regions of pixels are found and isolated from the rest of the X-ray image using a watershed algorithm and morphological operations (erosion and dilation). *b)* Feature extraction: the regions are measured and shape characteristics (diameter variation and main direction of inertia based on invariant moments) are quantified. *c)* Classification: the extracted features of each region are analysed and classified using a k-nearest neighbour classifier. According to the authors, the method is robust and achieves a good detection rate.

6 Defect recognition using linear classifiers

In [1] a method to welding defect detection is proposed. In a first step, called image pre-processing, the quality of the X-ray image is improved using a median filter and a contrast enhancement technique. The defect detection follows the pattern recognition schema mentioned above: *a)* Potential defects are segmented in the X-ray image. *b)* Geometric and grey value features (contrast (C), position (P) , aspect ratio (a), width-area ratio (e/A), length-area ratio (L/A) and roundness(R)) are extracted. The correlation between features and each considered defect class (slag inclusion, porosity, lack of penetration and undercutting) was evaluated by analysing the linear correlation coefficient. *c)* The most relevant features were used as input data on a hierarchic linear classifier [2].

In order to achieve a higher degree of reliability for the results, radiographic standards from International Institute of Welding were used, with 86 films containing the main defect classes. The experimental results shown that the features P and e/A are able to classify the classes undercutting and lack of penetration. Nevertheless, the six mentioned features are required to obtain a high performance by classifying the porosity and inclusion defects.

7 Inspection of moving pieces

An approach to inspect moving aluminium castings automatically from a sequence of radioscopic images was presented in [5]. The method, based on the tracking of potential flaws [4], consists of the following five steps: 1) An image sequence of the specimen in motion is taken without frame averaging, avoiding the gliding of the specimen. 2) In order to remove the blur caused by the motion of the casting, a restoration of the radioscopic images is performed. 3) Potential defects in each image of the sequence are identified using a single image processing filter, which is independent of the structure of the specimen. In this step the identification of real defects is ensured while the false detections are not considered. 4) In order to reduce the number of false detections in the potential defects, a classification is performed using a statistical approach [6], where more than 70 features in more than 10.000 regions were analysed. An interesting result was obtained using texture features and a newly developed contrast feature. 5) Finally, the remaining potential defects are matched and tracked in the image sequence using algebraic multifocal constraints. The key idea of this step is to consider as false alarms those potential defects which cannot be tracked in the sequence. The reliability of the method has been verified on real radioscopic image sequences recorded from cast aluminium knuckles in motion with known defects. Using this method the real defects can be detected with high certainty. This approach achieves impressive discrimination from false alarms.

8 Conclusions

In this paper, six new approaches in X-ray testing for automated defect recognition were presented. Since the reported experiments do not use the same data, it is evident that an objective comparison is very difficult. In addition, some methods are not reproducible because they were developed by the industry, where the know-how details may not be published.

However, it is clear that the recent progress in computer technology allows the handling of various theoretical and experimental problems in science and technology which were inaccessible before. Currently, the processing of image sequences, and the use of sophisticated filters in digital image processing –to cite a few– are possible. In automated defect detection in die castings the throughput cycle time is principally determined by the mechanical speed[1].

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