AUTOMATED INSPECTION OF MOVING ALUMINIUM CASTINGS

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Abstract

In this paper, we report the results obtained by inspecting castings in motion. Our method consists of following steps: an image sequence of the specimen in motion is taken; potential defects in each image of the sequence are segmented and classified; finally, the potential defects are tracked in the image sequence. The key idea is to consider as false alarms those potential defects which cannot be tracked in the sequence. Using this method the real defects can be detected with high certainty.

1. Introduction

The automated inspection of aluminium castings is usually done by analysing stationary radioscopic images taken at programmed positions of the specimens. The advantage of these methods are as follows: a) a number of frames of the same scene can be averaged in order to reduce the inherent noise of the x-ray images; b) using a priori knowledge of the expected regular structure in the view, a bank of filters can be designed to generate an error-free reference image from the taken image. Thus, the computed reference image is compared with the real radioscopic image, and flaws are detected at the pixels where the difference between them is considerable. However, the disadvantages are as follows: a) to get the programmed positions of the specimen, it must be moved and braked several times by the manipulator. Thus, the specimen may so slide, that it might not be exactly placed at the required position, the filter might not work correctly and the detection may fail; b) normally, the filters are configured and tuned manually for each casting and position. Configuration of filters and setting of best views involve a couple of workweeks. Additionally, this operation must be carefully optimised in order to minimise false detections while maximising detection probability.

In order to reduce the mentioned problems, a new method for the automated inspection of moving aluminium die cast pieces with the aid of monocular X-ray image sequences was presented recently in [Mery01]. The new method inspects moving aluminium castings automatically from a sequence of radioscopic images. This method 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, the radioscopic images are restored.

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. Applying this criterion to detect flaws, the parameter tuning of the image processing method is quite simple.

4) In order to reduce the number of false detections, the potential defects are classified using a statistical approach.

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.

In this paper, we report the results obtained by inspecting castings in motion. The paper is organized as follows: Section 2 describes briefly our defect detection method. In Section 3 we present our experimental results. Finally, in Section 4 we give concluding remarks.

2. The Method

In this Section, the inspection method is outlined. This method can be find in [Mery01].

2.1 Image Acquisition

Digital radioscopic images are acquired using a CCD camera and a frame grabber. A sequence of radioscopic images (without frame averaging) is taken by moving the casting. The position of the casting must be registered at each radioscopic image. This information is required by the matching and tracking algorithm.

2.2 Image Restoration

The acquired images are blurred because they were obtained from a moving casting. Since the images are formed by interlaced scanning convention [Castleman96], where each image is made up of two interlaced fields, the images can be restored by sub-sampling the rows obtaining only the odd rows of the original image [Mery00a].

2.3 Segmentation of Potential Defects

In the first step, an edge detection procedure based on the Laplacian-of-Gaussian is employed to find abrupt changes in grey values (edges) in every X-ray image. Here, the zero crossings of the second derivative of the Gauss low-pass filtered image are detected [Castleman96]. These edges are then utilised to search for regions with a certain area and a high contrast level compared to their surroundings [Mery02b]. Other methods for segmenting hypothetical casting defects, such as the PXV 5000, can be used [Mery00b].

2.4 Classification of Hypothetical Flaws

In order to discriminate the false alarms in the segmented potential flaws a classification must be performed. The classification analyses the features of each region and classifies it in one of the following two classes: *regular structure* or *hypothetical flaw*. A statistical approach that classifies the potential defects can be found in [Mery02a].

2.5 Tracking of Hypothetical Flaws in the Sequence

In the fifth step, the attempt is made to track the hypothetical casting defects in the sequence of images [Mery00b]. False detections can be eliminated successfully in this manner, since they do not appear in the following images and, thus, cannot be tracked. In contrast, the true casting defects in the image sequence can be tracked successfully because they are located in the position dictated by the geometric conditions.

The tracking of the hypothetical casting defects in the image sequence is performed according to the principle of multiple view analysis [Hartley00]. Multi-focal tensors are applied to reduce the computation time. Following a 3D reconstruction of the position of the hypothetical casting defect tracked in the image sequence, it is possible to eliminate those which do not lie within the boundaries of the test piece.

Finally, a verification can be done as follows: Using the least squares technique [Faugeras93] one can estimate the corresponding 3D point from the centre of gravities of the tracked regions. Additionally, one can calculate the size of the projected flaw as an average of the sizes of the identified flaws in the tracking. In each view a small window is defined with the estimated size in the computed centres of gravities. Afterwards, the corresponding windows are averaged. Since flaws must appear as contrasted zones relating to their environment, we investigate if the contrast of each averaged window is high enough. With this verification it is possible to eliminate all remaining false detections.

3. Experimental Results

In this Section we report the obtained results by inspecting a knuckle (see Fig. 1). A sequence of nineteen radioscopic images of the casting in motion (without frame averaging) was taken. The automated flaw detection in aluminium castings based on the tracking of potential defects in a radioscopic image sequence requires the knowledge of the position of the specimen at each image. This task is however very difficult, because both frame grabber and manipulator should be synchronised in order to know exactly where the casting is located while the image is been taken.

Figure 1: Aluminium casting used in the experiments: a knuckle [Jaeger99].

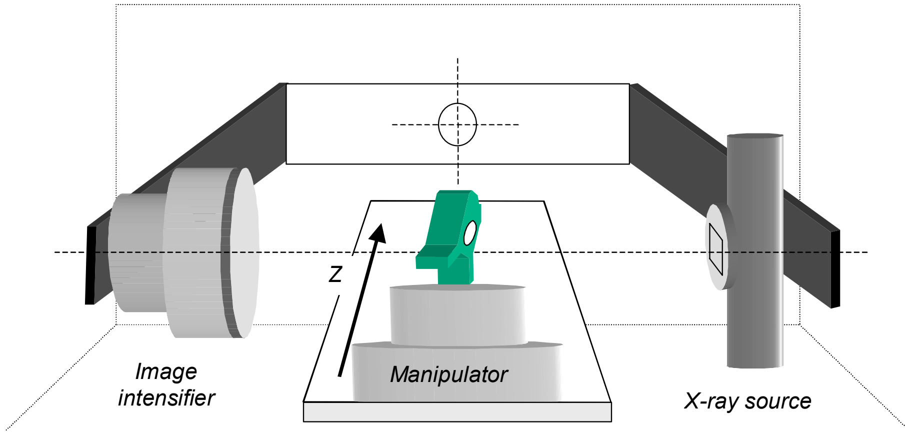

Figure 2: Motion of the casting in the X-ray testing stand.

	Segmen-tation	Classifi-cation	Matching in 2 images	Tracking in 3 images	Tracking in 4 Images	Verification
False alarms	15.098	1.140	412	119	16	0
Real flaws	53	52	49	49	47	8
Total	15.151	1.192	461	168	63	8

Table 1: Results obtained in the image sequence.

In this experiment the required synchronisation was achieved by programming a rectilinear motion of the casting with a start and end position. Since both the speed of the manipulator and the frame capturing frequency are constant, the 3D coordinates of the casting by each position (at each image) can be estimated. The experiment is shown in Fig. 2.

In this casting there were 8 defects that were produced by drilling small holes. The diameters of the holes were 2 mm. Since the sequence consists of 19 images, each defect was captured in many images. Thus, we have in the sequence 55 defects. The results obtained in each step of the method are summarised in Table 1. After the segmentation and classification only 52 of them were detected (3 of the existing 55 flaws were not identified because their contrast were poor). Additionally, there were 1.140 false alarms in this step. The number of false alarms were reduced considerably by the matching in two images (1.140 → 412), and the tracking in three (412 → 119) and four images (119 → 16). The reduction of the false alarms is in these three steps 98.6%. Finally, after the verification the number of false alarms is reduced to null without discriminating the real flaws. Our objective is then achieved: the 8 real defects were separated from the false ones.

In Fig. 3 and Fig. 4 we can see how impressive is the elimination of the false alarms. In these figures we illustrate the results obtained on the images 9 and 15 of the sequence. In Fig. 3 there were 4 defects, however only 3 of these real defects were identified by the classification. Nevertheless, the not detected flaw was identified in other images of the sequence. For this reason, we can reconstruct the position of the missed defect in image 9. This is illustrated by the arrow in the verification of Fig. 4.

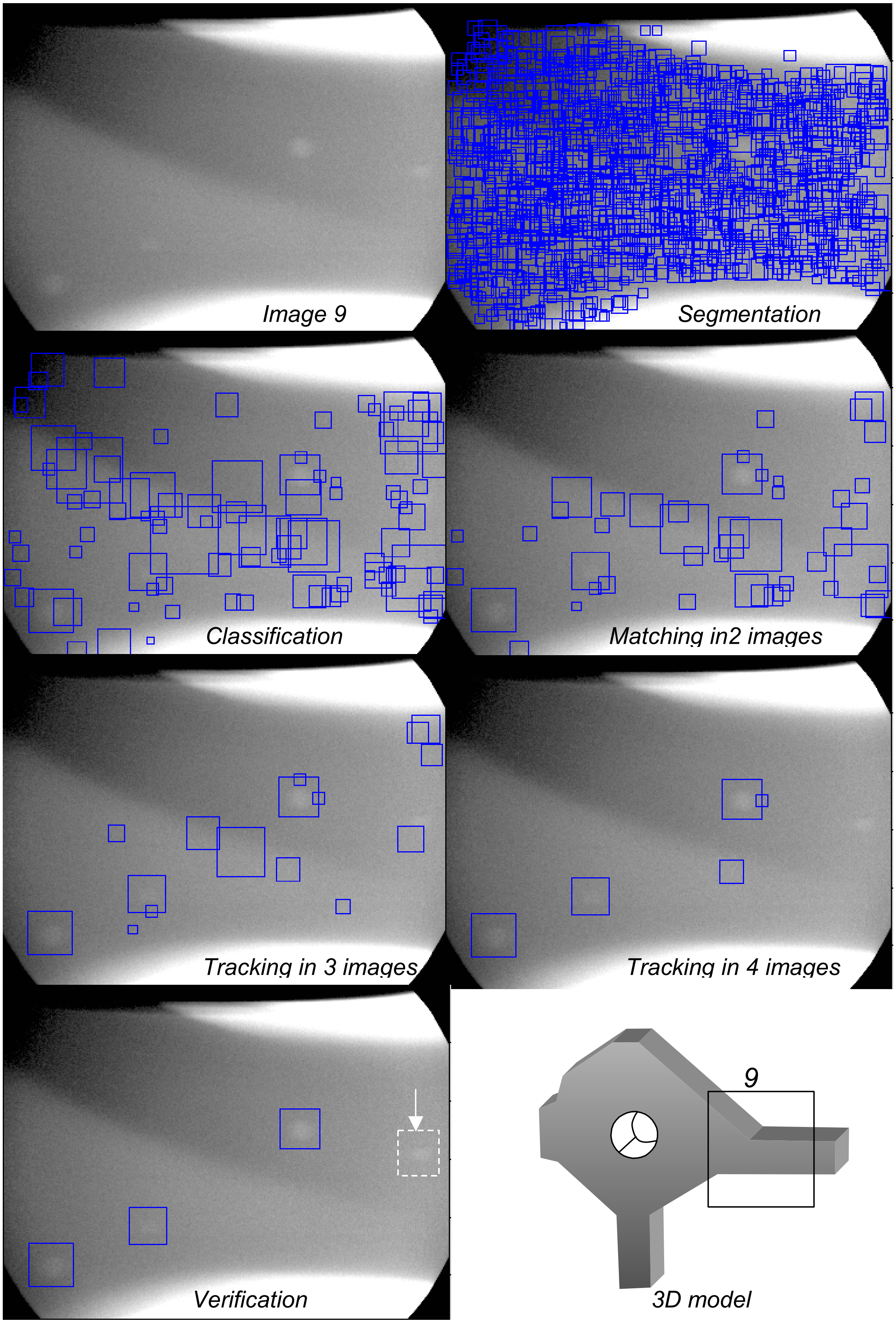

Figure 3: Results on image 9 with 4 defects.

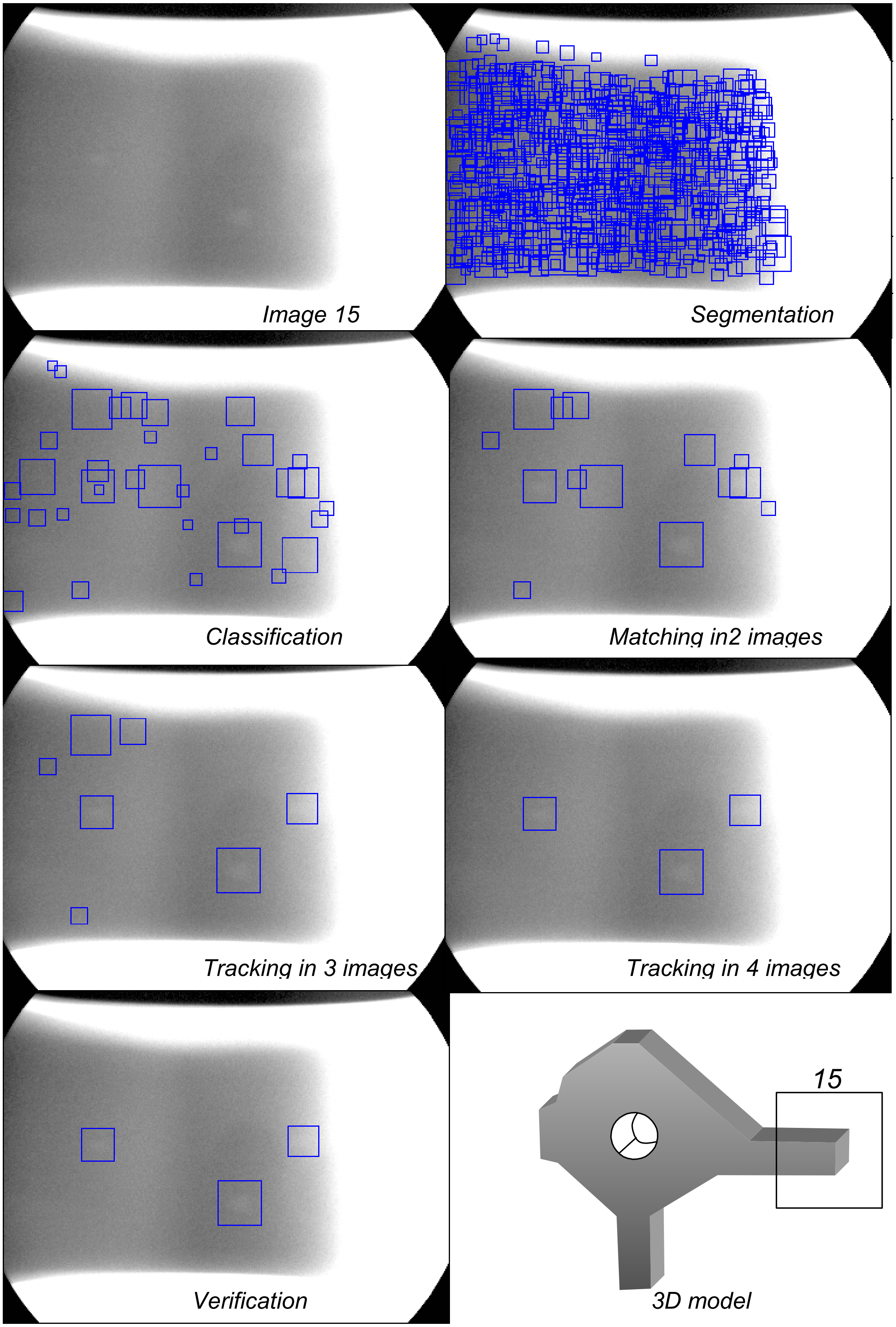

Figure 4: Results on image 15 with 3 defects.

4. Summary

A new method for automated flaw detection in aluminium castings using multiple view geometry has been developed. Our method is very efficient because it is based fundamentally on a two-step analysis: identification and tracking. The idea was to try to imitate the way a human inspector inspects radioscopic images: first relevant details (potential defects) are detected, followed by tracking them in the radioscopic image sequence. In this way, the false detections can be eliminated without discriminating the real flaws.

The great advantage of our first step is the use of a single filter to identify potential defects, which is independent of the structure of the specimen. Nevertheless, its disadvantages are as follows: a) the misclassification error rate is enormous; b) the efficiency could be poor if the flaws to be detected are very small and located at the edge of a structure; and c) the identification of regions is time-consuming. Contrarily, the second step is highly efficient in both discrimination of false detections and tracking of real defects, and is not time-consuming, due to the use of the multiple views tensors.

The elements of this method were tested in a laboratory prototype on real and simulated cases and the preliminary results of detection experiments are promising (100% of all casting defects recognised in 16 image sequences with no false detections). Above and beyond this, the required computing time is acceptable for practical applications [Weiske01]. As the performance of this method has only been tested on a limited number of image sequences, it will be necessary to analyse a broader databank.

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