X-RAYS IMAGE SEGMENTATION

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ABSTRACT

The aim of this work which enter in a research project on NDT, is to conceive an aid system for interpretation and taking decisions on imperfections in metallic fusion welds. we have studied and tested several segmentation techniques based on the two approaches (contour and regions). A quantitative analysis will be applied to extract some relative geometrical parameters. To the sight of these characteristics, a first classification will be possible.

However there is no unique segmentation, for each application, it is necessary to choice the appropriate technique, with the adapted parameters. This study has permitted to conclude that we cannot favour one method in relation to the other one. The basic idea is to use the two approaches in a single process that exploit the advantages of one technique to overcome the drawbacks of the other one. In this paper we propose a new method by combining estimation, enhancement, edge detection and a region growing in a an Intelligent process.

keywords: defects, edge detection, filtering, region growing, segmentation, X-rays image.

1. INTRODUCTION

Due to the degraded quality and the small size of the defects, X-ray films are sometimes difficult to inspect. The interpretation of such images is often likely to be affected by a certain subjectivity of the human operator. It seems very interesting to introduce techniques that are operator independent. The aim of this work which enter in a non destructive testing research project, is to conceive an aid system to interpret and take decisions on metallic fusion welds imperfections. The inspection method used is based on X(or Gamma)-radiography, the propagation of excited photons into the material produce an image on a photographic film. The inspected welded areas of industrial sites can present several kinds of defects, they may occur during the fabrication process, or caused in-service by an excessive load, etc.

We present in this paper, the result of a welding defects characterisation technique of welded joints radiogram images. To this end, the image will be segmented in order to put failures in obviousness. Image segmentation is a fundamental stage in any artificial vision system. It allows producing a compact description that can be characterised by edges or by homogeneous regions. Image edges represent a very rich information and have been extensively studied. The "regions" approach is complementary to the "contour" approach. however it does not provide the same results. We have studied and tested several segmentation techniques based on the two approaches. There is no unique segmentation, for each application, it's necessary to choice the appropriate technique, with the adapted parameters. Indeed each technique have its advantages, drawbacks and its limitations. The aim of each one is closely related to the application in question.

A new tendency consist of combining these two approaches in order to obtain a robust segmentation by exploiting the advantages of one method to reduce the drawbacks of the other one. We will present :

- Optimal edge detection algorithms. The edge extraction algorithms is based on an optimal multiscale filter use. allowing an extraction at several scales; thus, they can be efficient on many kinds of images ;
- Some region segmentation algorithms based on one of the following categories: Split and merge techniques, Clustering techniques, Classification techniques and Edge closing techniques.
- A new method by combining estimation, enhancement, edge detection and a region growing in a an intelligent process.
- A quantitative analysis to extract some relative geometrical parameters will be applied.

To the sight of these characteristics, a first classification will be possible. We proceed as follow:

- Acquisition and digitising of radiogram image .
- pre-processing (restoration, noise reduction, contrast stretching) in order to enhance the quality of the images ;
- segmentation by region extraction or edge detection ;
- defect selection ;
- defect contour following to extract some geometrical characteristics ;
- defect nature decision (e.g. linear or spherical, etc.).

Step 2 and 3 are executed automatically by the new intelligent co-operative segmenter proposed.

Several practical results will be presented and commented.

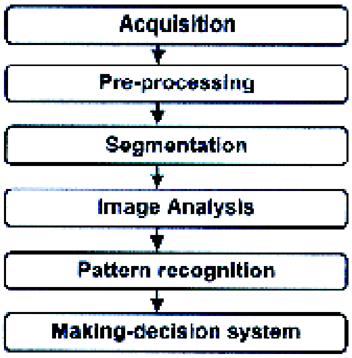

Figure 1. Flow chart of the NDT project

This study describes one stage of a software tools realisation, which facilitate and improve the task of the expert for x-ray image interpretation and decision-making. We are interested by the first four stages of this flow chart. Defects intervening in pieces are listed by official norms. For segmentation needs, we have divided the set of defects in two categories, volumetric and linear defects. A defect is considered as linear if its width is twice inferior to its size, all the rest are considered as volumetric defects.

2. PROBLEM PRESENTATION

We use the X or gamma rays power penetrating to detect possible heterogeneities in inspected pieces. These rays are absorbed by the matter crossed, essentially by the photoelectrical effect.

Due to the great number of disruptive factors, the visual information provided by an X or gamma ray image is complex. The processed images are characterised by three particular phenomena:

1. leak contrast between the defect and the image bottom ;

2. image bottom granular aspect, perceived as a bottom noise ;

3. gradient bottom image presence characterising the thickness variation of the inspected sample which can harm the small dimensions and bad contrast defects detection .

The importance of these phenomena varies from one image to an other according to the nature of the metal, the thickness of the piece and the type of radiation employed. For all the reasons described above, we have to perform some operations, described in section 3:

2.1 Pieces and defects nature

Inspected pieces are of variable forms and thickness. Risky zones are those submitted to important physical constraints. Two types of pieces are mainly controlled:

welds, levelled or not levelled;

cast pieces, such as elbows.

Defects intervening in pieces are listed by official norms. For segmentation needs, we have divided the set of defects in two categories, volumetric and linear defects. A defect is considered as linear if its width is twice inferior to the size of the grain, all the rest are considered as volumetric defects.

3. PRE-PROCESSING

3.1 Contrast stretching

When the grey level dynamic range in the image processed is small, usually because of a poor illumination or a non uniform lighting , it's possible to increase this dynamic range by a histogram transformation. This transformation affect the intensity distributions and increase the contrast.

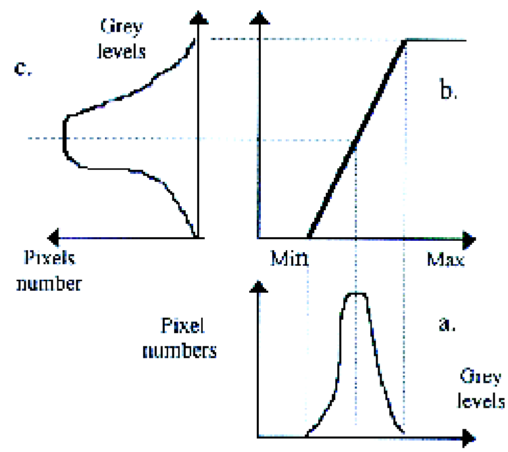

Figure .2 Contrast stretching principle
Original image histogram
Transformation function
The modified histogram

3.2 Noise Reduction by filtering

Noise reduction can be achieved by convolution of the image with an appropriate filter. $g(x,y) = \iint f(x,y)h(x-\alpha,y-\beta)d\alpha d\beta$.

h(x,y) is the impulse response of the used filter. There exist several types of filters that can be used, like gaussian filter ,exponential filter, median filter... . With x-ray images, we usually use a contrast stretching and gaussian or median filter .

4. IMAGE SEGMENTATION

The segmentation allows to compact the huge amount of information contained in the original image and preserve only significant information. It can be divided into two categories ;

Edge detection, when we are interested by object shapes ;

Region segmentation, when we are interested by the image element contents.

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4.1 Edge detection [1][2][3]

An optimal edge detection algorithm is described here. In this method, the operator must satisfy the three criteria suggested by Canny[1]: Good detection, Good localisation and Unique response. The solution retained by Canny and improved by

Deriche[3] can be implemented in the next manner.

- Smoothing of the image with the filter : $f(x)=-ce^{-\alpha|x|}\sin(\omega x)$ for $x \in]-\infty, +\infty[$, using a recursive implementation;

- Determination of the contour direction and its amplitude;

- Extraction of the local maxima;

- Thresholding by hysterisis of the image of the local maxima.

4.2. REGION SEGMENTATION[4][5][6][7]

Region segmentation techniques can be classified into four methods : split and merge methods, region growing methods, classification methods and edge closing methods.

These methods are based on homogeneity criteria that partitions an image into homogenous regions. This can be expressed by the following formal definition

Let I represent the image, and E a partition of I, composed of connected sub-regions R_i .

$E=\{R_1, R_2,\ldots,R_n\}$ with $I=\cup R_i$ ($\forall$ i=1,...n) and $R_i \neq \Phi$ ($\forall$i=1,...,n).
Let P a logical predicate applied over the points in set R_i and Φ is the null set.
E is a segmentation of I with respect to the predicate P if :
- $P(R_i)$=TRUE; $\forall$ i=1,...n
- $P(R_i \cup R_j)$=FALSE $\forall$ i$\neq$j / R_i and R_j are adjacent.
A segmentation closely depend on the similarity criteria and on the strategy used similarity can be measured in terms of grey levels, mean value computed on the entire region or in a small neighbourhood or texture measurement computed on a centred window.

4.2.1 Split and merge methods :

The split and merge methods represents the fundamental methods in region segmentation. it's composed of two phases : splitting and merging . The splitting process consist of subdividing an entire image successively into smaller and smaller regions so that, for any region R_i the homogeneity criteria is valid, otherwise this region will be divided too, this operation is recursively applied to each of the resulting regions until the homogeneity criterion is fulfilled.
The resulting image is usually over-segmented and would have many false boundaries. In the second phase (merging) all pairs of adjacent regions are tested and merged if their union satisfies the similarity criterion. The merging phase permit to obtain a maximal number of connected regions.
With a quad-tree structure, it's possible to generate this subdivision (fig. 3).

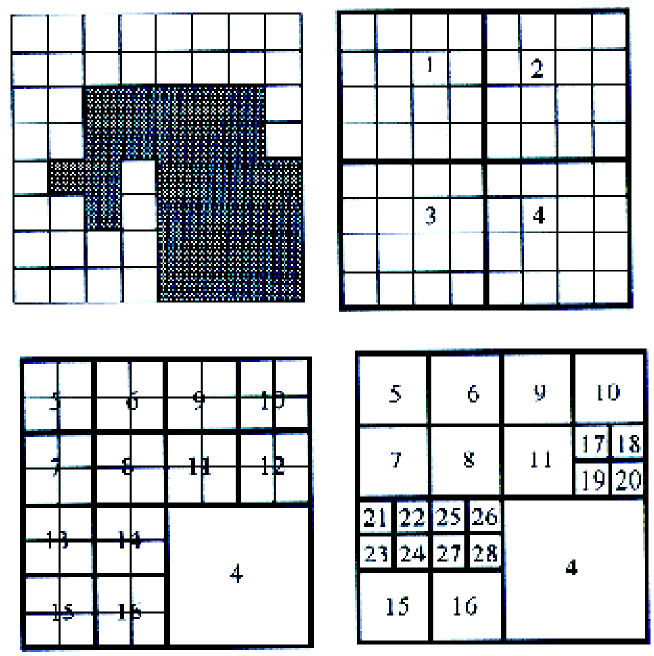

Figure 3. Segmentation with a Quad-Tree structure

4.2.2 Region growing methods :

Region growing segmentation consist of grouping iteratively sets of connected pixels into larger regions. The segmentation process is controlled by local region properties. These methods can be divided into two classes: Pixel aggregation and Iterative grouping of pixel sets.

4.2.3 Classification methods:

The region segmentation can be processed by automatic classification or using histogram. Two automatic classification are commonly used, classification based on K nearest neighbors and hierarchical rising classification.

Intensity classification is often based on image histogram which shows different peaks, each corresponding to one region and adjacent peaks are likely to be separated by a valley. The problem posed is to determine thresholds corresponding to these valleys. In this framework we can use the entropy of the Grey level histogram to select thresholds (fig.4).

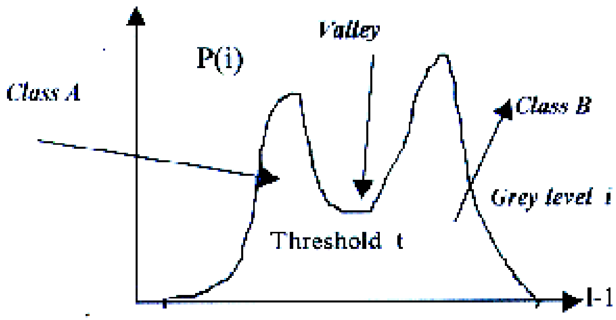

Figure.04 Histogram classification

4.2.4 closing contours Methods

Assuming the duality existing between contours and regions, Closing contours methods can be considered as a region segmentation methods. After an edge detection operation, the contour map is completed. In order to bring more relevant information to ulterior processing stages. Perfectly closed contours are necessary to define the different regions by a connected component analysis.

5. DISCUSSION AND PROPOSED CO-OPERATIVE METHOD

The study of the advantages and drawbacks of the different segmentation methods, leads us to the following concluding remarks :

- The edge approach generally gives a localised contours when transitions are abrupt, but always presents discontinuities;
- An edge detection don't satisfy directly the mathematical formalism used to define a theoretic segmentation, it's based on the duality existing between an edge detection and a region segmentation (a contour define a region boundary, and a region is automatically delimited by a closed contour) ;
- A region segmentation use a similarity criteria to detect homogenous regions. nevertheless their boundaries are not sufficiently precise; the choice of a similarity criterion and its parameters can affect considerably the position of a region boundary.
- The extraction of textured regions is well done by a region segmentation.

A comparison between the two approaches (edge and region segmentation) has shown that neither edge or region segmentation can provide alone an ideal segmentation. The future of image analysis is probably in the co-operation between these two approaches. A co-operation technique permit to exploit the advantages of each method in order to reduce the drawback effects of the other one.

5.1 proposed co-operative method

Here we give a brief description of our proposed method :

- Estimation of both the noise affecting the image and textured zones;

- Image enhancement by appropriate filters based on the precedent estimation step;

- Construction of a preliminary edge map (with a robust operator), allowing to obtain high precision on image objects border;

- Performing a region growing segmentation constrained by the edge map and extraction of the regions boundaries; the growing process start from seeds (randomly, extracted from a preliminary region segmentation,….);

- Elimination of small chains situated far from the boundary of any region;

- correction of regions boundary positions that are far from a « sure » edge segments, or merging of two regions that are not separated by a significant boundary (ex : the sum of the gradient along the boundary is less than a certain threshold);

- contour closing of the first edge map controlled by the region segmentation map;

- creation of the final segmentation by confrontation of the two maps (edge and region).

6. QUANTITATIVE ANALYSIS : Geometrical features extraction

We have implemented all segmentation techniques described above, in an interactive software. The operator can chose and adapt the appropriate segmentation technique with the desired parameters. Some geometrical features can be extracted using a contour following such as length, width, surface, form, median axes of the selected defect. The selection is easy and can be done interactively using the mouse.

Example : linear or volumic defect

The geometrical measurements previously extracted help the making decision system to decide for example whether the defect is linear or not. This defect discrimination into two categories is considered as a first attempt for defect classification. To this end we define a linearity ratio (R_L) :

R_L =Length / width.

If R_L is equal or near to "1", the defect is volumic (ex: porosity). , otherwise it is a linear defect (ex. cracks, lack of penetration).

7. RESULTS

We have created a specialised library for image processing tools including a wide variety of edge and region segmentation algorithms and image enhancement techniques on an IBM personnel computer, in C++ language. We have tested their efficiency on x-ray welded joints radiograms containing different defect types. The obtained results are very encouraging. This work represents a preliminary decision assistance stage, that will facilitate the expert task in defect detection

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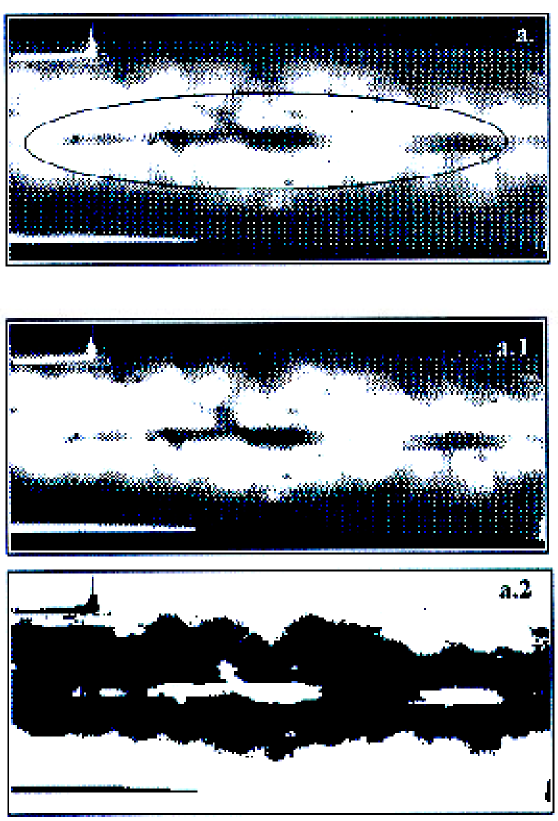

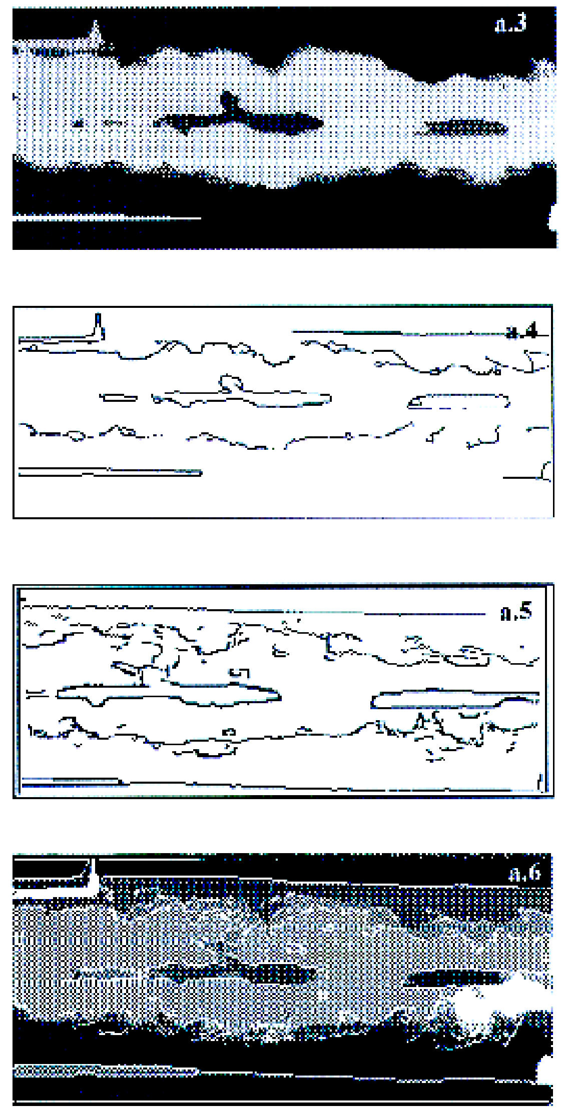

Figure 5: *a, welded joint image radiograms presenting a defect* (Lack of penetration). *a1, contrast stretching applied on image a a2 image segmentation of a by histogram classification, the optimal thresholds found is 250. a3 region segmentation by region growing technique(with local mean as similarity criterion) of images a with thresholds : 22. a4 result of closing contours. a5 edge detection results by Canny- Deriche method applied on film a. a.6 result of the co-operative method (edges are superposed on regions to show the relative compatibility between them)*