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COMPUTER AIDED PROCESSING OF INDUSTRIAL RADIOGRAPHS

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Abstract

The main purpose of this article is to show a method, which allows digital storage, retrieval and transmission through computer network of radiographs. The complex system based on X-ray image database realises computer aided evaluation of industrial records in radiology. In addition it gives an efficient assistance for digitization, display, archiving and interactive evaluation of images giving substantial aid for radiologists. In the first part the versatile system is described, enumerating the main features it provides, in the second part I show the opportunity of automatic evaluation by the help of knowledge-based vision.

The system was developed for the Hungarian Gas Company Gázművek Rt., and the radiographs of power plant of Újpest are digitised and stored in the database.

Keywords: non-destructive testing knowledge base system, image database, artificial intelligence.

1. Introduction

Detection and analysis of low contrast flaws in radiographic images with high noise fields are topics of the current research in non-destructive evaluation of materials and articles during diagnostics. The poor quality of radiographic images is due to the physical nature of radiography as well as small size of the flaws and their poor orientation relatively to the size and thickness of the evaluated part. The known methods for radiograph analysis fail to detect low-contrast flaws and to make their meaningful analysis at all.

Originally a radiologist examines films by the help of a special device suitable to light through the dark X-ray records. This means that a radiologist can study only a part of the entire weld at a time. The method is not objective and requires mastery knowledge. Sometimes inspectors with several years of experience are of a different opinion whether a certain weld is satisfactory or not. The result of evaluation must be archived which requires much paperwork. In addition, due to the large number of records the storage of data is a critical issue, whereas the opportunity of rapid accessibility must be ensured [7].

Digital data management offers many advantages. Among others, radiologist can study the entire weld as long as necessary, archivation or data retrieval is much easier and through a computer network several radiologists can discuss a certain radiograph in spite of the large distance between them.

2. System Description

The system consists of two main parts. The task of the computer is to control the system and to provide a user-friendly interface and database management by the help of an application running under Windows. It realises the desired functions: digitisation, display, archivation, stitching, browsing of reference-database created by I.I.W. (International Institute of Welding) [3] and interactive evaluation of images.

The scanner is a critical part of the system. If digital images are of good quality, the further procedures of image processing are easier and probably the result is more precise.

2.1. Scanning

Typically X-ray records are very dark, their density is too high, so an ordinary scanner cannot light through radiographs. Of course, special scanners suitable for taking high-quality copies of radiographs exist but they are too expensive. So we have decided for AGFA Duoscan, which is capable to digitize in an acceptable quality.

A series of radiographs of an industrial pipe consists of several individual records, because there are several welds along one pipe and every weld is also recorded on more than one radiograph containing redundancy. The number of records depends on the diameter of the pipe and the length of original films.

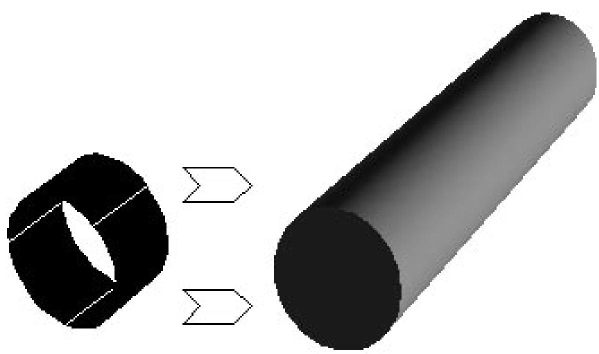

Fig. 1. One weld can be recorded onto more than one film. Overlapping films are fixed along the weld.

Because the typical length of films is 480 mm and the maximum scanning area is A4-size, one radiograph must be scanned twice, again with overlap.

During this process density range is the most important factor. Human intervention is necessary to obtain the best quality, because the density ranges of different radiographs are different. The process is hard to automate and the system performance would drop.

2.2. Stitching

As it described above, a weld consists of several – on the average six – overlapped records. It is often desirable that a radiologist can examine the pieces of a weld as one image without redundancy. In the classic way it cannot be solved, but using a computer-based digital system, this task is very simple.

The existing methods making a panoramic view from overlapping images cannot work properly on radiographs. The reason is that the neighbouring radiographs are not taken in the same phase, so the technical parameters can be different, and so the density value and the quality of the records can be different, too. The application can stitch two adjacent radiographs but the user has the chance to modify it.

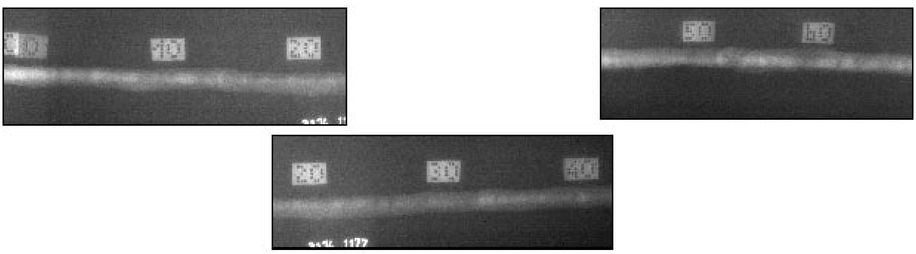

Fig. 2.a. Three overlapping records of a part of a weld. There is a bigger overlap on the left side.

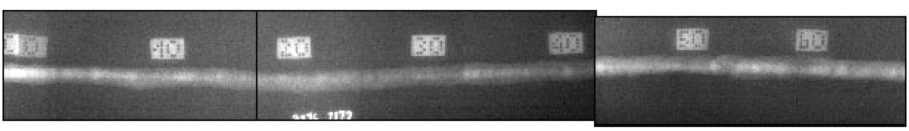

Fig. 2.b. Result after stitching

3. Automatic Knowledge-Based Analysis

3.1. Interactive Evaluation

Applying interactive evaluation, the first task of the radiologists is to mark those parts of images, where they suppose imperfections. Then the computer analyses that region of interest and by the help of implemented knowledge it tries to identify the problematic spots. Although the region of interest can be the whole image, the inspection can take a long time regarding the large size of the image. The result of the process can be a kind of imperfection or, on the contrary, the weld contains no discontinuity. The user can accept it or can perform further investigations.

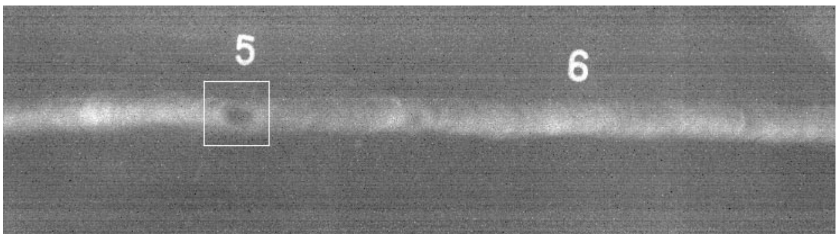

Fig. 3.a. Radiograph. Imperfection is marked by a rectangle.

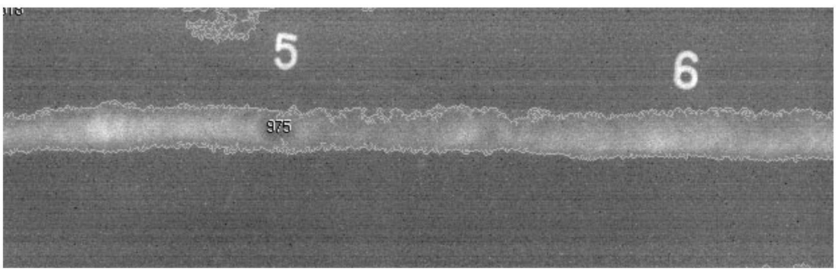

Fig. 3.b. Localisation of weld after segmentation (and pre-processing)

User can apply typical procedures during evaluation like edge detection, histogram analysis, line profile, distance measurement, area measurement, bounding rectangle etc.

During practical realisation of classification of imperfections, finding joints is very simple due to the sudden change between dark background and light weld. It can be solved by thresholding. The mean pixel value of joint, that characterises how dark the radiograph is, can be calculated also simply.

The real difficulty is to implement the knowledge and experience of radiologists especially when two well-known specialists are of different opinions examining the same radiograph in many cases.

The following table contains the typical imperfections and their brief descriptions:

Table 1. Different types of imperfections

Type of discontinuity	Description	Radiographic appearance
Porosity (Aa)	Cavities due to entrapped gas	Sharply defined dark shadows of rounded contour
Worm holes (Ab)	Elongated or tubular cavities due to entrapped gas	Sharply defined dark shadows of rounded or elongated contour depending upon the orientation of the defects
Slag inclusion (B)	Slag or other foreign matter entrapped during welding	Dark shadows of irregular contour
Slag lines (Bb)	Elongated cavities containing slag or other foreign matter	Dark lines, more or less interrupted, parallel to the edges of the weld
Lack of fusion (C)	Two-dimensional defect due to lack of union between weld metal and parent metal	Thin dark line with sharply defined edges. Depending upon the orientation of the defect with respect to the X-ray beam the line may tend to be wavy and diffuse
Incomplete penetration (D)	Lack of fusion in the root of the weld or a gap left by failure of the weld metal to fill the root	Dark continuous or intermittent line in the middle of the weld
Cracks (E)	Discontinuity produced by fracture in the metal	Fine dark line, straight or wandering in direction
Undercut (F)	A groove or channel in the surface of the plate along the edge of the weld	A dark line, sometimes broad and diffuse, along the edge of the weld

As it can be seen the dark blobs or a group of them inside a light weld means usually imperfections, so segmentation is needed firstly to find all of blobs inside the region of interest. Then characteristic features must be calculated, which are suitable to distinguish the different kinds of imperfections.

However, the question is what kind of statistical or geometrical properties are useful. The answer is that we need features which are invariant under translation, scale and rotation – if possible [2, 6].

The following global features satisfy these requirements and can be suitable for further classification: area, compactness, roughness, length, breadth, elongation, mean pixel, central moment, number of blobs.

Because of the large amount of appearing forms of imperfections, classic pattern recognition algorithms – like statistical or syntactical methods – are not so efficient.

In order to make the system more flexible, it is reasonable to apply artificial intelligence or knowledge base [1]. Hence not only the possible imperfections and their characteristic features, but also the basic principles of decision-making are stored, this ensures more efficient evaluation and more precise results.

3.2. Knowledge Representation

Knowledge is implemented of course by the help of the extracted features of blobs and rules [4]. Every rule consists of two parts: condition and conclusion. For example:

<If there are many little dark rounded blobs inside a small area> then <porosity>

<If there are one or more dark lines> then
<if those are at the edge of weld in parallel> then <undercut>
<if those are at the middle of weld in parallel> then <incomplete penetration>

The knowledge base is full of similar, but more complex rules. As it can be seen not only the features of blobs, but also their relation to weld or to another blob is taken into account.

The structure and the rules themselves can be modified easily – if it is necessary keeping the knowledge actual or making it more accurate.

Increasing the number of rules, decision-making and hereby the results become better, but the usage of them is more difficult and the response-time of the system will be longer.

3.3. Control Strategy

The control strategy of a system dictates how the knowledge will be used in that system [5]. The system RadexSys applies bottom-up hierarchical control.

It means that features are extracted from the image and grouped in some way, with no knowledge of the structure of the object. Only after a complete symbolic description has been constructed are object models used in matching procedure.

For the sake of simplicity, the application examines only the region of interest – the rectangle, drawn by the user. Because the mean pixel value, the position and orientation of the weld are known, and the hypothetical imperfections are relatively dark, a simple blob-searching algorithm can be suitable. After finding blobs, which are areas of touching pixels that are in the same logical pixel state (foreground or background), the system calculated the individual features described above. Actually the result is a table containing all necessary information which serves as a basis of decision-making. At the beginning of this process the set of potential imperfections must be radically reduced as much as possible, and then progressing systematically the system chooses the most likely type of discontinuity.

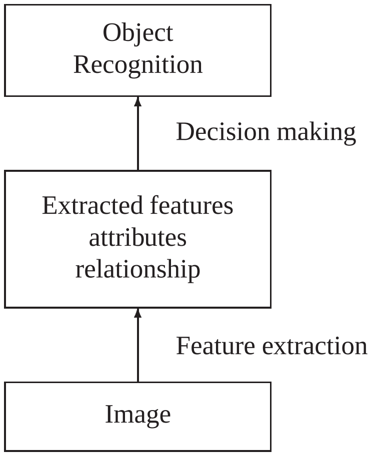

Fig. 4. Bottom-up hierarchical control

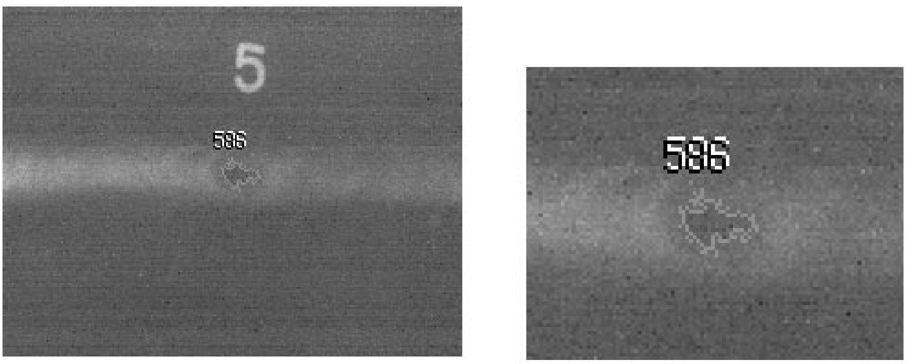

Fig. 5. Detecting imperfection. Incomplete penetration at 50 cm (Da;(515))

4. Results

The system was tested on two sets of images. At first, I choose radiographs from the collection of I.I.W., containing different type of imperfections. Since the quality of images was good, the imperfections were typical and they can be detected easily, the result was adequate. The system finds almost every discontinuity of the weld, and classifies them correctly.

However, the testing results of real radiographs were not so good. The smaller, but critical imperfections were not always detected, because they did not differ enough from their environment, or due to their size the system cannot distinguish them from blobs characteristic of every weld.

Usually the system finds only the obvious imperfections, but in the problematical cases, where radiologists would need some help, the system cannot give an efficient, certain assistance. The application cannot substitute human inspection, but it can make the evaluation easier and faster.

The success of perfect classification depends on the type of imperfection. Some of them (type B, C) extend along the whole weld, which makes them difficult to detect, and classify.

In general: the sharper the contour and the smaller the size are, the higher the probability of correct detection is.

5. Conclusion

This paper presents a possible way of automatic evaluation of industrial radiographs. With some modification, namely changing the knowledge base and rules, the system can be used for inspection of medical radiographs.

The success of proper classification depends strongly on the structure of the knowledge base and the applied rules, so the structure of the rules is critical. Refining or enlarging the set of rules, decision-making improves, so availability and efficiency of the system become better.

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